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An Anatomical Study of *Cycloloma atriplicifolium.*

BY DUDLEY J. PRATT.

A thesis submitted to the Department of Botany and the Faculty of the Graduate School in partial fulfillment of the requirements for the master's degree.

INTRODUCTION.

CYCLOLOMA ATRIPLICIFOLIUM is a coarse annual native to the central part of North America. The typical form of this hardy xerophyte is found in the Niobrara sand hills, according to the Phytogeography of Nebraska ('09). There the small, slender, moderately branched form found in other localities becomes a great bushlike type (5 dm. to 2 meters in diameter and 1 meter high), called the giant tumbleweed, which is well adapted to the tumbling habit because of its subglobose, compact top and innumerable seeds. The spreading tops and close aggregations of these tumbleweeds, sometimes several hectares in extent, crowd out other plant growth from the sandy plains or summits of the sand hills. On tilled soil, however, the smaller form of this weed is not hard to combat. The Iowa Geological Survey ('13) states the weed is easily exterminated in that state by cultivation.

There has been no anatomical work done on *Cycloloma*, recorded in the literature accessible to the writer, but there has been some ecological study of the genus, and of the species *atriplicifolium.* Bentham and Hooker ('80), and Engler and Prantl ('89), classify *Cycloloma* under the Chenopodieæ, and describe the genus. Solereder ('08) discusses the anatomical features of the Chenopodieæ, but does not include *Cycloloma* among the genera mentioned. Descriptions of both the genus and species are given by Britton and Brown ('13), Coulter ('09), and Gray ('08).

The plant studied was collected by Professor W. C. Stevens, of the University of Kansas, September 5, 1915, on dry upland

four miles southeast of Pratt, Kan. When gathered it was placed in a two per cent formalin solution. The specimen is ordinary in size, and is fresher than those commonly found in the early fall, due, no doubt, to the unusually frequent summer rains.

METHOD OF PROCEDURE.

The methods of anatomical study employed by Stevens ('11) were followed. Microchemical tests were made on sections cut free-hand with the razor. Microtome sections of all sizes of stem and root were made, and sections were made of five regions of stem and root imbedded in both paraffin and celloidin. Region I (fig. 29, *m''*) of the stem was cut within 5 mm. of a young branchlet tip; region II (fig. 29, *o''*) within 1 to 3 cm. of a young branchlet tip; region III (fig. 29, *h''*) from a branchlet of medium size; region IV (fig. 29, *r''*) from the base of a main branch; and region V (fig. 29, *s''*) from the main axis, 7 cm. above the root, where the diameter is approximately 1.5 cm. The sections of the five regions of root correspond in size to the five regions of stem. The general drawings mapping out tissue regions were made from material not imbedded, but the detail drawings were made for the most part from material imbedded in paraffin, but in a few instances in celloidin. All drawings were made with the use of the projectoscope.

THE STEM.

The main axis of the stem in my specimen is 15 cm. long; it varies in diameter from 2 cm. close to the root to 1 cm. where the last branches go off. From this main axis arise uniformly twelve erect branches, which are not straight but irregularly zigzag, and which are diffusely branched to fill out the globose contour of the plant. The bases of the two uppermost main branches unite to form the tip of the main axis of the stem. The branching habit of a main branchlet is shown in fig. 1. The stem has a glabrate surface, and a light green color with a purple tinge; but parts of the main axis and the large branches are colored a light brown. Due to a well-developed vascular system and collenchyma tissue of the ribs, even the branchlets are very resistant to breaking.

The zones of tissue for the five regions of stem are mapped out in figs. 2, 3, 4, 5 and 6; the detail of the tissue for the first four upper regions of stem is found in figs. 7, 8, 9, 10, and 11. The tissues of the five regions of stem, from the epidermis to the pith, inclusive, are described in the following paragraphs. Discussions

of the primary vascular bundles and of the woody cylinder of the stem follow.

The epidermis consists of one layer of cellulose-walled cells, the lumina of which appear rectangular or circular in cross section. The cell walls show more thickening down through the regions II and III (figs. 8, *a*, and 9, *a*); and the lumina of the cells in region IV (fig. 10, *a*) have become very small because of this thickening. The external wall, which is thicker than the other walls, does not have a cutinized layer in young and medium-sized stems, but develops a cuticle, which, although a very thin film in region I (fig. 7), is more prominent in regions II and III (figs. 8 and 9). The greatest thickness of the cuticle is only .002 mm., attained in region III (fig. 9). The cuticle stains a bright reddish-orange color in chloroiodide of zinc, and bright red in Sudan III and alcannin.

The epidermal cells of the ribs of the stem are elongated longitudinally (figs. 12 and 13) approximately four times their tangential dimensions (fig. 9, *a*), and show a slightly greater dimension tangentially than radially (fig. 9, *a*). The epidermal cells other than those on the ribs of the stem are slightly elongated longitudinally or have relatively equal longitudinal (figs. 14 and 15) and tangential (fig. 9, *a*) dimensions, and have greater tangential than radial dimensions (fig. 9, *a*). The inner tangential wall of the epidermal cells joins up in a somewhat irregular line with the primary cortex cells (fig. 10, *a*). In surface view *Salsoli kali* also has lengthened epidermal cells of the ribs and isodiametric epidermal cells between the ribs, according to Solereder ('08).

The epidermis of very young stems is thick.y covered with clothing and glandular hairs (figs. 16 and 17). As would be expected, the hairs are not so numerous in region II as in region I; still fewer hairs are found on region III, and usually only basal portions of hairs remain in region IV. The hairs of the stem are discussed later with the hairs of the leaf.

The stomata of the epidermis of the stem are like those described for the leaf in this article, and are almost as numerous, there being 117 per sq. mm. (Figs. 12 and 14.)

Subepidermal groups of collenchyma (fig. 9, *b*) projecting as ribs; groups of parenchyma (fig. 9, *c*) intervening between the ribs; also parenchyma (fig. 9, *i*) between the collenchyma groups and the starch sheath; and the starch sheath (fig. 9, *d*), make up the primary cortex.

The collenchyma cells in the outer part of the rib, then the cells situated farther in, are differentiated from the ground meristem by thickening of the cellulose walls as shown in regions I and II (figs. 7, *b*, and 8, *b*). The collenchyma, which is the sole strengthening tissue in region I, contains chloroplasts. In cross section the cells are usually as large as the epidermal cells or larger. A longitudinal view of the collenchyma cells of region III is shown in fig. 18. In region IV (fig. 10, *b*) we see the collenchyma has reached a greater development than higher up, and the lumina of the cells are smaller because of the thickening of the cell walls.

In most ages of stem seven groups of collenchyma, corresponding to the seven prominent ribs, are present. There are three main ribs in region I (fig. 2), giving this region of the stem a triangular shape. Ten ribs are present in region V (fig. 6).

The chlorophyllous tissue between the ribs is made up of ordinary parenchyma cells, the walls of which are thickly lined with chloroplasts (fig. 7, *c*). There are no intercellular spaces among these cells in region I (fig. 7, *c*); a few occur in the outer part of the chlorophyllous tissue of region II (fig. 8, *c*); and quite a number are present in region III (fig. 9, *c*).

On certain sides of the stem the cell walls of one to six rows of parenchyma cells, just exterior to the starch sheath, in region IV, (fig. 10, *o*) suberize their cell walls. These cells resemble the cells of the starch sheath in shape and size, and have thicker walls than the other parenchyma cells of the primary cortex. A phellogen layer arises in the parenchyma of the primary cortex on various sides of the stem in region V and below and forms cork (figs. 6, *b′*, and 19, *b′*) and lenticels (figs. 6, *a′*, and 20, *f′*). The epidermis and cells of the primary cortex exterior to the newly formed cork are sloughed off. According to Georghieff (*fide* Solereder, '08), the cork arises in the primary cortex in *Kochia* also, an allied genus. Solereder ('08) states that cork may be formed externally or internally in the Chenopodieæ; internally it is generally formed in the pericycle.

The starch sheath is well defined in all regions of stem by the shape and size of its cells, most of which have a long tangential dimension (fig. 9, *d*) and are lengthened longitudinally (fig. 21, *d*). The radial and the outer tangential walls of the starch sheath cells in portions of region V have become suberized.

The ground tissue of the pericycle has just been formed from the ground meristem in region I (fig. 7, *e* and *f*). In this region of stem two areas of the pericycle are distinguishable by the size of

their cells. The outer area of the pericycle is made up of small cells, which contain chloroplasts in very young stems (fig. 7, *e*), and the inner area of the pericycle is made up of much larger cells (fig. 7, *f*). There are three areas of pericycle in region II (fig. 8, *e′*, *e″* and *f*), and all the pericycle cells are larger in region II than in region I (fig. 7). The areas of pericycle *e′* and *e″* in fig. 8 correspond to the area of pericycle *e* in fig. 7. The cells in the outermost area of the pericycle (fig. 8, *e′*) have cellulose walls. In the areas of pericycle *e″* and *f* of fig. 8 the cell walls are lignified.

There is also an outer area of unlignified pericycle in regions III and IV (figs. 9, *e′*, and 10, *e′*). These cells are shown in longitudinal section of region III in fig. 21. The outer longitudinal strip of these cells, two cells deep radially, includes bast fibers. As seen in a cross section of region IV (fig. 10, *f′*) the bast fibers are arranged single or in short chains. This arrangement is found in nearly all the Chenopodieæ, according to Solereder ('08), who states, "it rarely consists of a closed sclerenchymatous ring, and is mostly composed of isolated groups of sclerenchymatous fibers." The occurrence of a sclerenchymatous pericycle is held to be an ordinal character in the Chenopodieæ by Georghieff (*fide* Solereder ('08).

A few bast fibers, irregularly arranged, also occur in three tangential rows of pericycle cells, just interior to the outermost row, in cross sections of region V (fig. 22, *f′*) and below. The bast fibers are approximately twice as broad as the wood fibers (figs. 23 and 24). The fibers stain a reddish-brown or a brilliant yellow in chloroiodide of zinc.

The lignification of cell walls in the areas of pericycle *e″* and *f* of fig. 9 in region III is more complete than in the corresponding areas of pericycle in region II (fig. 8). The cells of the area of pericycle *e″* of region III are shown in longitudinal section in fig. 25. In certain cross sections of region IV the two outer rows of cells of the central area of pericycle (fig. 11, *e″*) have thick lignified walls, and the outer cells in this area of pericycle have cellulose walls. The cell walls in the innermost area of pericycle are cellulose (fig. 11, *f*).

Generally all the cell walls in pericycle areas *e″* and *f* in fig. 11 of region IV are cellulose, or are very slightly lignified. The cell walls of the corresponding areas of pericycle in all regions of the stem below region IV are cellulose, or are very slightly lignified. (See the areas of pericycle of fig. 26, *e″* and *f*, in region V.) The

cells included in these areas of pericycle resemble pith cells, in shape and nature of cell walls.

The cell walls of the primary medullary rays are cellulose upward from a little above region II, as shown in fig. 7, *g*, of region I, and remain cellulose in certain sections of region IV (fig. 11, *g*). The cell walls of all but a few of the innermost cells of the primary medullary rays are lignified in regions II and III (figs. 8, *g*, and 9, *g*), and in some sections of region IV. The primary medullary ray cells, the walls of which are delicately pitted, are shown in longitudinal sections of region III in fig. 27.

The lignification of the cell walls in the pericycle areas *e''* and *f* (fig. 9) and the primary medullary rays in regions of stem from region IV up to a little above region II would seem to give strength and elasticity to these regions of stem. Probably the anomalous structure which forms a greater part of the woody cylinder of the stem in region IV and below (as described later) strengthens these regions of the stem sufficiently to make unnecessary the lignification of the cell walls of the pericycle areas *e''* and *f* and the primary medullary rays oftentimes in sections of region IV, and in all sections of regions below.

The pith cells are shown in longitudinal view in fig. 28. The cells of the pith do not break down to form hollow spaces, but persist in older sections of the stem. Generally the cell walls of the pith stain a deep purple color in chloroiodide of zinc, but also stain a delicate red with phloroglucin.

THE PRIMARY VASCULAR BUNDLES.

The primary vascular bundles are mapped out for region I in fig. 2; region II, fig. 3; region III, fig. 4; and region IV, fig. 5. Usually one or two of the primary vascular bundles of larger size are situated opposite each of the main ribs of the stem in regions I, II, and III. The course of the primary vascular bundles in the stem is mapped out in fig. 29, *j*. In regions above region IV the leaves remain on the stem, and the leaf traces traverse a portion of the anomalous structure (fig. 29, *t''*). The course of the leaf-trace bundles out of the stem up through the petiole into the leaf is discussed later. The leaf traces are broken apart in region V and below (fig. 29, *u''*) by further development of the anomalous structure.

The primary vascular bundles are differentiated into the phloëm and xylem elements in region I (fig. 30, *h'* and *j'*). In cross section some of the cells of the phloëm elements have walls unusually

thick for this region. This feature is discussed later. The central strip of procambium and the young water tubes of the primary xylem can be clearly discerned (fig. 29, *i'* and *a'''*). Immediately down the stem from region I the leaf-trace bundles appear in the pericycle (fig. 31, *k*), where they are crossing out into the leaf, and the cambial layer of the primary vascular bundles is discernible (fig. 31, *n'*). Some secondary phloëm and xylem have been formed by the cambial layer in region II (fig. 32, *m'* and *o'*).

In longitudinal sections of region III the sieve tubes, the companion cells and the phloëm parenchyma cells are discernible, as shown in figs. 33 and 34, *b'''* and *c'''*. In cross section the sieve plates are difficult to distinguish, their pits being very small (fig. 34, *d'''* and *f'''*). Certain sieve tubes have thickened their cell walls (fig. 34, *d'''*) and others have not (fig. 34, *f'''*). The cambium is active yet in a few of the bundles. Spiral and annular tracheæ of primary xylem are shown in figs. 36, 37 and 38. The parenchyma of primary xylem does not lignify.

In the secondary xylem of the primary vascular bundles the tracheæ have circular lumina, and are prominent. The tracheæ are pitted, having slightly elongated, bordered pits (fig. 39), or are of reticulate type (fig. 40). Solereder ('08) states, the tracheæ in the Chenopodieæ usually have simple pits, but mentions the genus *Axyris* as an exception. Georghieff (*fide* Solereder, '08) records scarlariform perforations with oblique, almost longitudinal, bars in *Axyris amarantoides*. At intervals portions of the cross walls of the elements of the tracheæ remain (fig. 39). The wood parenchyma cells of the secondary xylem of the primary vascular bundles are ordinary in size and shape, and have few and only inconspicuous pits (fig. 41). Wood fibers were not found to occur in the xylem of the primary vascular bundles. The fiber tracheids, which are rather few, vary in size and shape, and have bordered pits (fig. 42).

In the primary vascular bundles of region IV (fig. 43, *m'* and *o'*) more secondary phloëm and xylem are present than in the corresponding bundles of region III. The wood parenchyma of the secondary xylem of these bundles in this region of stem is well lignified.

A leaf-trace bundle with an active cambial layer is shown in fig. 31, *k*, and an older leaf-trace bundle in region IV is shown in fig. 44. The leaf-trace bundles do not grow to be very large. The cambial layer in most of the leaf-trace bundles of region III has ceased its activity. Solereder makes the following statement con-

cerning the development of the leaf-trace bundles in the Chenopodieæ: "The leaf-trace bundles sometimes possess considerable growth in thickness, and thus delay the appearance of the anomalous growth (*Camphorosma* and *Echinopsilon*, as also *Blitum virgatum*, *Chenopodium murale* and *C. hybridum*, according to De Bary, *Kochia prostrata* according to Georghieff.)"

As seen in some cross sections of region IV, and regions farther down the stem, the primary vascular bundles are very irregularly arranged, are more numerous than in regions higher up, and have the appearance of being imbedded in the pith. (See figs. 5, *j*, and 6, *j*.) This appearance is due to the fact that the cells in the areas of primary pericycle *e''* and *g* of fig. 26 and the cells of the primary medulary rays (fig. 44, *g*) in these regions of stem resemble pith cells in shape, and appearance of cell walls, which have remained cellulose or are very slightly lignified.

A few cells of the area of pericycle, *e''*, which have cellulose walls, are shown in longitudinal section of region IV in fig. 46. In regions of stem from region IV on down, parts of the anomalous xylem, which is first formed exterior to the primary vascular bundles by anomalous growth, resemble pith. This is shown for region V in fig. 26. A discussion of the origin and nature of the anomalous tissue appears later in this article.

The following statement quoted from Solereder ('08) throws light upon the pith-like appearance of the primary pericycle and primary medullary rays in most sections of region IV and all sections of regions below: "In the Nyctagineæ, Amarantaceæ and Chenopodiaceæ the ground tissue situated between the primary vascular bundles and the tissue formed at the commencement of the activity of the secondary meristem is occasionally differentiated like a pith, and in such cases the primary vascular bundles appear as apparent medullary bundles." Solereder also states that the vascular bundles, which he terms medullary bundles, appear in certain members of the Chenopodieæ, and adds that their development in this order shows that these bundles are rarely true medullary bundles, but are the normal leaf-trace bundles. According to Georghieff (*fide* Solereder), true medullary bundles occur in *Acroglochin persicarioides* Moq.

Evidently the primary vascular bundles of *Cycloloma atriplicifolium* have the same appearance in region IV and regions on down the stem as have the bundles which Solereder terms apparent medullary vascular bundles.

THE WOODY CYLINDER.

In region II there is a beginning of the formation of a woody cylinder, consisting of xylem groups of primary vascular bundles (fig. 3, *j*), and lignified pericycle (fig. 3, *e''* and *f*) and primary medullary rays (fig. 3, *g*), and holding imbedded the strands of phloëm belonging to the vascular bundles (fig. 3, *j*). The woody cylinder of region II is mapped out in fig. 3, and the detail of the tissue of the woody cylinder in a portion of a cross section of region II is shown in fig. 8. The woody cylinder in region III, mapped out in fig. 4, is larger than in region II, due to the larger size of the cells of the areas, *e''* and *f*, of the primary pericycle (fig. 9) and primary medullary rays (fig. 9, *g*) included, and to the addition of anomalous xylem (fig. 4, *m*), formed by anomalous growth.

The anomalous growth consists in the formation of one or several broad zones of xylem around the stem, and a narrow, broken zone of tissue (made up of phloëm groups, secondary medullary rays, and from one to several rows of pericycle cells exterior to the phloëm groups and secondary medullary rays), having thin cell walls and located just exterior to each xylem zone, both kinds of zones being formed by broken rings of arcs of secondary meristem, which arises successively around the stem in the pericycle. The arcs in each successive ring of arcs of secondary meristem are active for a time, but cease their activity before the next younger ring of arcs arises.

For convenience in presentation of the anomalous structure, frequently in this article the broad xylem zones are designated as xylem zones, and the narrow, broken zones having thin cell walls, as phloëm zones.

The number of cells in the outer area of pericycle is considerably greater in region III (figs. 4, *e'*, and 9, *e'*) than in region II (figs. 3 and 8). On various sides of the stem, arcs of the inner rows of the cells in this area of pericycle have just produced a secondary meristem in region III (fig. 47, *n*), and other secondary arcs, having arisen earlier on other sides of the stem, are in different stages of progress (figs. 48, *n*, and 49, *n*). Anomalous xylem has been formed on some sides of the stem in region III by the secondary arcs of meristem, as shown in figs. 4, *m*, and 29, *p''*, and 48, *m*. On some sides of the stem the secondary arcs have not yet arisen, as shown in fig. 9, *e'*.

In regions of stem just below region III, the arcs latest to be differentiated in the first ring of secondary arcs have arisen; and

a xylem zone around the stem (figs. 29, *q''*, and 50, *p*) and a phloëm zone located just exterior to the xylem zone (figs. 29, *q''*, and 50, *q*) have been formed in regions of stem a little farther down. The outer and inner borders of the two zones are very irregular in boundary (figs. 29, *q*, and 50, *p* and *q*), due to the varied activity of the first ring of secondary meristematic arcs, which is described in the following paragraph.

As seen in cross section, the formation of the xylem zone, and the narrow zone just exterior to the xylem zone, is as follows: Various arcs of the secondary meristem form radial strips of xylem on their inner side, and small, isolated groups of phloëm on their outer side (fig. 51, *n''*); some secondary arcs form radially longer strips of xylem on their inner side and do not form phloëm on their outer side (fig. 51, *o''*); and other secondary arcs form radial strips of xylem, and secondary medullary ray tissue between the phloëm groups (fig. 51, *p''*). What else can this area of tissue (figs. 50, *r*, and 51, *r*) located between the groups of secondary phloëm be called other than a secondary medullary ray? The xylem-phloëm zone is mapped out in fig. 50, *p* and *q*.

The outer two rows of cells of the phloëm zone, shown in figs. 50, *t*, and 51, *t*, are pericycle cells; the rest of the narrow zone is made up of the phloëm groups (figs. 50, *s*, and 51, *s*) and the secondary medullary rays (figs. 50, *r*, and 51, *r*); and the phloëm zone is interrupted by certain radial, anastomosing strips of xylem (figs. 50, *u*, and 51, *u*).

As seen in cross section, the newly formed anomalous xylem zone (figs. 50, *p*, and 51, *p*) coalesces with the outer part of the lignified primary pericycle (figs. 50, *e''* and 51, *e''*). The anomalous xylem stains a light yellow color in chloroiodide of zinc (figs. 50, *p*, and 51, *p*); the part of the woody cylinder formed from lignified pericycle and primary medullary rays, a yellowish-brown (figs. 50, *e''*, *f*, and *g*, and 51, *e''*, *f*, and *g*). The anomalous xylem and the primary tissue included in the woody cylinder stain uniformly with phloroglucin.

In region IV (figs. 5, and 29, *r''*; and 10) more xylem zones, and the phloëm zones alternating with the xylem zones in a radial direction, have been formed by the successive rings of arcs of secondary meristem, arising in the pericycle. The arcs in the rings of secondary meristematic arcs, arising later than the first ring of secondary arcs, do not have their origin directly exterior to the phloëm groups previously formed by the next older ring of secondary arcs, as illustrated in fig. 48, *n*, where a secondary arc

has just arisen. A similar arc, forming the fourth ring of xylem in region IV, is shown in fig. 52, *n*. The arcs, in a ring of secondary arcs of one region of stem, anastomose both tangentially and radially with the arcs, in the corresponding ring of secondary arcs, in the region of stem below (figs. 5, *n*, and 29, *n*).

The number of xylem-phloëm zones on the various sides of the stem may differ, ranging from two to four in region IV (fig. 5); from five to eight in region V (fig. 6); and from eight to twelve in the part of the main axis having the greatest diameter.

The xylem groups of the primary vascular bundles are not included in the woody cylinder in region IV; for only the outer part of the primary pericycle, on various sides of this region of stem, lignifies completely enough to be included as a part of the woody cylinder (figs. 5, *e''*, and 11, *e''*), and the rest of the woody cylinder in region IV is anomalous tissue, composed of the xylem zones holding imbedded the phloëm zones, as shown in figs. 5, and 29, *r''*. On other sides of the stem, in region IV, all the cells of the primary pericycle (fig. 5, *e'*, *e''*, and *f*) and primary medullary rays (fig. 5, *g*) have cellulose walls, and are not included in the woody cylinder. In all regions of stem below region IV, none of the cell walls of the primary pericycle (fig. 25, *e'*, *e''* and *f*) and primary medullary rays (fig. 44, *g*) have lignified deeply enough to be included in the woody cylinder, and the woody cylinder in these regions of stem has been formed by anomalous growth only. (See figs. 6, and 29, *s''*.)

The relative radial breadth of the xylem-phloëm zones is shown in cross section in figs. 5 and 6. The anomalous zones are complete rings around the stem, or as segments of rings have an irregularly concentric arrangement in cross section, and undulate slightly in a radial direction in their course around the stem (figs. 5 and 6). The xylem zones and the phloëm zones anastomose both tangentially and radially (figs. 5, *u*; 6, *u*; and 29, *u*).

The xylem zones are generally made up of the tracheæ, a few lignified parenchyma cells bordering the tracheæ, and the numerous wood fibers (fig. 51, *p*). The wood fibers are shown in longitudinal view in fig. 24. In some sections of region V and below, the tissue lying on the inner side of some of the xylem zones is made up entirely of wood fibers (fig. 53, *p''*); and the remainder of the xylem in each of these xylem zones (about 80 per cent of the entire zone) is composed of wood parenchyma and tracheæ (fig. 52, *q''*).

One or several inner rows of cells, or almost all the inner half, of the innermost anomalous xylem zone, on certain sides of stem in some cross sections of region V (fig. 26, *c′*), and in all cross sections of regions of stem below, is made up of thin-walled cells, which resemble pith cells in cross section in shape and relative size and have cellulose or slightly lignified walls (figs. 54 and 55). The rest of this zone is of the usual xylem structure (fig. 25, *d′*).

Spiral tracheæ are not present in the xylem of anomalous growth. The tracheæ are arranged in radial rows associated with other tracheæ scattered through each xylem zone (figs. 26 and 51), or have a very irregular arrangement (figs. 50 and 53). The lumina of the tracheæ are usually circular in shape, but some are oval. The lumina of the tracheæ range from .010 to .080 mm. in diameter, being relatively quite large, when compared with the lumina of the tracheæ in other members of the Chenopodieæ. Solereder ('08) states the usual diameter is .015 to .045 mm. in the Chenopodieæ.

The lumina of the tracheæ are usually larger in the xylem zones (fig. 53, *p*) external to the innermost xylem zone (fig. 51, *p*), but the number of tracheæ and the sizes of the lumina of the tracheæ are the same for relative areas of each of the xylem zones exterior to the innermost xylem zone.

In cross sections the wood fibers appear irregular in shape and arrangement (fig. 53, *o″*), or may be rectangular or almost square and arranged regularly in radial rows (fig. 57).

The innermost anomalous phloëm zone has been described above. The other phloëm zones resemble the innermost phloëm zone, but are somewhat broader, being composed of larger groups of phloëm (fig. 57, *s*), larger regions of secondary medullary ray tissue (fig. 57, *r*), and two or more rows of pericycle cells located exterior to the phloëm groups and secondary medullary rays (fig. 57, *t*). The anomalous phloëm, although the cells are larger, resembles the phloëm of the primary vascular bundles (fig. 57, *s*). The cell walls of most of the secondary medullary rays lignify to some extent, but are thin (fig. 57, *t*). A few cells of a secondary medullary ray, the walls of which are cellulose, are shown in longitudinal section in fig. 59. The pericycle cells, in each phloëm zone, located exterior to the phloëm groups and secondary medullary rays (fig. 58, *t*) are similar to the cells of the secondary medullary rays in size, shape and nature of cell walls. A longitudinal view of these pericycle cells is shown in fig. 60.

As seen in cross section (figs. 5, *q*, and 6, *q*), the three inner phloëm zones are interrupted by numerous radial anastomosing strips of xylem (figs. 5, *u*, and 6, *u*). The other phloëm zones are traversed by a much lesser number of these (fig. 6). The radial strips of xylem are usually made up of wood fibers, as shown in fig. 10, *u*, although some contain tracheæ, as shown in fig. 56, *u*. The peculiar location of these radial anastomosing strips of xylem is due to the varied activity and anastomosis of the arcs of secondary meristem by which the radial anastomosing strips of xylem were formed. The anastomosis of the arcs of secondary meristem is described above. The phloëm zones in region V and below are joined up in cross section by radial anastomosing strips of tissue having cells which resemble the secondary medullary ray cells (figs. 6, *g'*, and 58, *g'*).

As seen in cross section, in the anomalous zones there are radial rows of cells having a radial dimension from two to four times as great as their tangential dimension (fig. 58, *g'''*). These radial rows of cells are narrow, being only one to four cells broad tangentially. None of these radial rows of cells in the sections examined extend entirely from the outer to the inner zone of anomalous growth, but generally traverse only a few zones. In the phloëm zones these cells are pericycle cells (fig. 58, *h'''*) and secondary medullary ray cells (fig. 58, *i'''*). In the xylem zones these cells resemble wood parenchyma in size and proportion, and have thick, slightly lignified walls (fig. 57, *j'''*).

As far as the writer has been able to ascertain, no use made of the anomalous structure by the plant has been mentioned in the literature available.

I am of the opinion that the anomalous xylem is an ample strengthening tissue, and serves principally for water storage, not so much for conduction. Probably the xylem of the primary vascular bundles conducts sufficiently for the transpiration of the leaves. The leaf-trace bundles traverse the two innermost anomalous xylem-phloëm zones in region IV (fig. 29, *t''*). Below region IV the leaf-trace bundles are broken apart by further anomalous growth (fig. 29, *u''*), and the leaves do not remain on this region of stem. Evidently from region IV on down the stem all the anomalous xylem zones are available for water storage.

The presence of many phloëm strands in the anomalous structure is quite striking, for it seems there is enough phloëm in the primary vascular bundles to conduct the photosynthetic products of the leaves. But there is much photosynthetic tissue in

the primary cortex in all regions of stem above region V, and on certain sides of the stem in regions below, on sides where the parenchyma has not been destroyed by the formation of cork within, and no doubt so much anomalous phloëm is necessary to store and to transfer the food, made in the photosynthetic tissue of the stem, for use in the rapid formation of the many anomalous xylem-phloëm zones. The photosynthetic products can be transferred readily from the parenchyma of the primary cortex through the starch sheath and pericycle to the anomalous phloëm. The products of photosynthesis may also travel from one anomalous zone to another because of the anastomosis of these phloëm zones (fig. 29, *g'*), and finally to the phloëm of the primary vascular strands, whence presumably it would go to the nutrition of the seeds later in the season.

The anomalous structure found in the Chenopodieæ occurs in all the Chenopodiaceæ having considerable growth in thickness, and is found in the Nyctagineæ and the Amarantaceæ, according to Solereder ('08), in his review of the anatomical features of Chenopodieæ. He quotes from Morot the following statement regarding the course of the development of the anomaly: "Secondary rings or arcs of meristem (the latter anastomosing reticulately) arise in centrifugal succession in the pericycle (internally to the bast fibers, where these are present) and produce secondary vascular bundles as well as conjunctive tissue of varying structure. The xylem portions of these secondary vascular bundles always arise on the inner, the bast portions on the outer side of the secondary meristem."

According to Morot (*fide* Solereder, '08), the appearance of the anomaly in transverse sections of the stem varies greatly between two main types, relatively to the nature of the meristem, and of the tissue intervening laterally between the bundles in each ring of secondary bundles. In the first type the broad, woody rings alternate in the radial direction with rings of tissue having thin cell walls; the woody zones are traversed by medullary rays of varying breadth, the cells of which have thin or lignified cell walls. The rings of tissue with thin cell walls consist of phloëm portions of the vascular bundles associated with variable amounts of a tissue, which Morot terms "parenchymatous conjunctive tissue." In the second type, which occurs more commonly than other types, the vascular bundles are arranged concentrically, spirally, or irregularly, and the bundles are imbedded in tissue, which Morot terms "prosenchymatous interfascicular tissue."

The phloëm groups, which vary in size and are sometimes very small, are associated with lignified or unlignified parenchymatous tissue.

The types of anomalous structure found in the Chenopodiaceæ, Amarantaceæ, Nyctaginaceæ and Tetragonieæ, and in species of *Mesembryanthemum* and *Phytolacca*, are not adaptive anomalies, but merely cases of variation of design; for the abnormal features may be various in the several members of a family, and even in the different species of a single genus, and yet not be connected with the ecological relations of the plants concerned, according to Haberlandt ('14). He makes the following statement concerning the place of origin of the secondary arcs of meristem: "According to Morot, each new arc of cambium arises opposite a phloëm group and extends laterally on each side until it meets an older cambial layer. Herail, on the contrary, maintains that each new cambium begins to develop at one end as a lateral continuation of an antecedent cambial layer; then it extends gradually across the leptome, and sooner or later rejoins an older strip. Leisering believes that both possibilities may be realized."

Anomalies have been found in many lianes as well as in certain small shrubs and herbs, according to Haberlandt ('14), but Hill ('01) has examined an anomaly in *Dalbergia paniculata*, a tree native to south and central India. He states, the anomalous structure is "extremely interesting and equally surprising for a tree attaining the height of sixty feet." From a preliminary examination of the wood, Hill describes the appearance of the anomaly in cross section somewhat as follows: narrow zones of tissue (termed by Hill as "narrow zones of the nature of phloëm") and broad zones of woody tissue alternate in a radial direction. The anomalous zones are traversed by narrow medullary rays. The following statement in regard to the structure of the anomaly in the stem of *Dalbergia paniculata* are quoted from Hill: "By the examination of a transverse section it may at once be seen that the narrow, abnormal zones are of the nature of phloëm, which is accompanied by a certain amount of cambium. This cambium is situated on the side nearer the center of the stem and abuts directly on the xylem elements. . . . , The wood is made up of the usual elements; that is to say, vessels, fibers, and parenchyma."

THE ROOT.

The root is a taproot, light brown in color, with approximately the same length and diameter as the main axis of the stem, and having only a few lateral roots attaining much size. Many very small rootlets, with suberized walls for several of their outer layers of cells, are retained throughout the main root. One to several of these arise from each of the numerous grooves in the root. The lateral roots and rootlets extend into the central xylem cylinder or into the first, second or third formed anomalous xylem zone. It has the same habits of growth in thickness as the stem.

The general areas of tissue for regions I, II, III, IV and V are mapped out in figs. 61, 62, 63, 64 and 65. The detail of tissues in regions I, II, III and IV can be found in figs. 66, 67, 68 and 69.

The resemblance in structure of the corresponding tissue of root and stem is so close it is not necessary to give a detailed description of the root here. In very young roots (fig. 66, *b'*) the two or more outer rows of cells become suberized to form cork. Apparently no cork cambium has arisen. Later a few layers of cells, located just interior to these two or more outer rows of primary cortex cells having suberized walls, suberize their cell walls. The cells of the starch sheath can not be clearly discerned, as in the stem, except in portions of certain sections. In figs. 61 and 66 are shown the central xylem cylinder, the phloëm groups of the primary vascular bundle, and the primary medullary rays. The water tubes of the central xylem cylinder are large, and stand out well when stained with phloroglucin (fig. 66, *m''*).

Rings of arcs of secondary meristem arise successively in the pericycle, as in the stem, and form anomalous xylem-phloëm zones. An arc of secondary meristem is shown in fig. 70. In region II (figs. 62 and 67) the anomalous growth has begun, and a second xylem-phloëm zone is starting to form in region III (fig. 63); and the fourth zone, in region IV (fig. 64). From eight to ten xylem-phloëm zones are present in region V (fig. 65); ten to fourteen in the region of the main root having the greatest diameter.

The zones of the anomalous structure are more nearly concentric and broader radially than in the stem. The anomalous zones anastomose both tangentially and radially, but the anastomosis of the first three xylem-phloëm zones is not so frequent as in the corresponding zones of the stem. The three innermost xylem-phloëm zones of the anomalous structure are more nearly concentric than in the stem (fig. 64). The number and arrangement

of tracheæ for unit areas in cross sections is the same as in the xylem zones exterior to the innermost anomalous xylem zone of the stem, but there are relatively more tracheæ having the larger diameter (fig. 65). Commonly the part of the xylem lying on the inner side of the zone is made up entirely of wood fibers (fig. 69, *m''*), and about 80 per cent of the xylem zone has the usual structure found in the xylem zones of the stem (fig. 69, *n''*). The walls of the pericycle cells included in each phloëm zone lignify slightly. The cell walls of the secondary medullary rays usually remain cellulose.

Traversing the anomalous zones in cross sections of the root, as in cross sections of the stem, are the radial rows of cells having a radial dimension from two to four times as great as their tangential dimension (figs. 65, *g'''*, and 69, *g'''*). In the zones of tissue designated as phloëm zones in this article these cells are pericycle cells and secondary medullary ray cells; in the xylem zones these cells resemble wood parenchyma in size and proportion. The walls of many of these cells are lignified, as are the walls of similar cells in the stem; but all these cells in certain sections of the root have cellulose walls, and in many regions of the root are in direct connection with the vascular elements of the very small rootlets, which extend from the exterior grooves into the central vascular cylinder or inner anomalous xylem zones of the main root. The absorbed water is readily transmitted by these cells, included in the radial strips, to all parts of this region of root.

THE LEAF.

The leaves of *Cycloloma atriplicifolium* are alternate and oblong-elliptic, with pointed lobes. Like the stem, the leaves are colored a light green, and are purplish tinged. The leaf is not unusual in structure, and possesses many of the leaf characteristics of the Chenopodieæ mentioned by Solereder ('08). The areas of tissue in a cross section of a typical leaf are mapped out in fig. 71.

The epidermal cells are much more irregular in shape, as seen in cross section, than in the stem (figs. 72, *a*, and 73, *a*). The cells of the upper and lower epidermis are shown in surface view in figs. 74 and 75, and the lengthened cells of the upper epidermis over the main rib are shown in fig. 76. The cell walls of the epidermis are cellulose, except the cuticle, which reaches a thickness of only .001 mm. Solereder ('08) states that in spite of the xerophilous character of many species of Chenopodieæ, the cuticle rarely attains a considerable thickness.

Many clothing hairs (fig. 77) and a few glandular hairs (fig. 78) can be found on the young leaves, but only a few hairs are present on older leaves. Most of the hairs are located at the edge of the leaf, but on young leaves quite a number are scattered over the upper and lower surfaces.

Each clothing hair is seated on a prominent basal cell, above which it consists of a chain of one or more short cells (fig. 77, *a''*), distinguishable by a very thin cuticle from a long terminal portion of one or several cells (fig. 77, *u'*) having thin cellulose walls without cuticle.

The glandular hair has a basal portion made up of a chain of two or more cells with a very thin cuticle (fig. 78, *a''*), and a terminal portion consisting of a row of three or more cells, usually all but the end cell being conspicuous on account of cell contents and a thin cuticle. Cell contents are present in the large spherical or ovoid terminal cell of certain of these hairs (fig. 78, *b'*). The wall of this terminal cell stains blue in chloroiodide of zinc, and does not stain appreciably in Phloroglucin or Sudan III. The contents of the hair cells is discussed in the section on the nature of cell contents.

There are two types of hairs on the stem similar to the hairs on the leaf. A clothing hair of the stem is shown in fig. 16, and a glandular hair is shown in fig. 17.

The stomata are of ordinary type (figs. 74, 75 and 76). Solereder ('08) gives the absence of a definite type of stoma as a noteworthy feature in the leaf of the Chenopodieæ. The cuticle extends over the guard cells (fig. 73, *f''*). The stomata are almost as numerous in the upper epidermis as in the lower epidermis of the leaf, there being 122 stomata per sq. mm. in the upper epidermis, and 128 per sq. mm. in the lower. Usually the long axes of the stomata, as seen in surface view, are placed at an angle with the main rib of the leaf, although many are parallel with the main rib in both young and old leaves. The transverse arrangement of the stomata is not uncommonly shown by narrow leaves in the Chenopodieæ, but also occurs on the stem, according to Solereder ('08).

The mesophyll of the leaf is approximately 65 per cent photosynthetic tissue and 35 per cent water-storage tissue (figs. 71, *c* and *d*; 72, *c* and *d*; and 73, *c* and *d*). Solereder mentions the differentiation of the mesophyll into assimilatory and aqueous tissue as one of the leaf characters of the Chenopodiaceæ correlated with their dry-land habitat.

The water-storage tissue is made up of large cells centrally located and lying next the border parenchyma adjacent to the vascular elements (figs. 72, *d*; 73, *d*; and 79, *d*). The vascular elements of the leaf are imbedded in the mesophyll in closer proximity to the lower than the upper epidermis (figs. 71, *g*; 72, *g*; and 73, *g*). Under the upper epidermis of the leaf is a palisade layer of mesophyll, and just below there is a layer of mesophyll parenchyma joining up with the water-storage tissue (figs. 70, *l'''* and *m'''*, and 71, *l'''* and *m'''*). A surface view of a bleached leaf embracing the epidermal, the palisade and the vascular bundle systems is shown in fig. 80. Between the water-storage tissue and the lower epidermis is a layer of mesophyll two or three cells deep (figs. 71, *n'''* and 72, *n'''*). The intercellular spaces in this are too small and regular to form a typical spongy tissue. The mesophyll cells are shown in tangential section in fig. 81. A typical spongy tissue has not been observed in any species of the Chenopodieæ, according to Solereder.

In the main rib of the leaf collenchyma cells join up the water-storage tissue and cells of the lower and upper epidermis, as shown in figs. 71, *b*, and 72, *b*, and the main rib projects out farther on the under side of the leaf than on the upper, there being more collenchyma in the under side of the main rib. Collenchyma serves as a strengthening tissue in the tip of the leaf and also in the tip of each lobe of the leaf, as is shown in fig. 82.

The venation of the leaf is mapped out in fig. 83, which is made from a whole leaf bleached and cleared by the method of Peace ('11). To hasten the removal of the abundant calcium oxalate crystals, the leaves treated were left over night in 10 per cent hydrochloric acid after being treated with 5 per cent potassium hydroxide solution. The leaves were then stained with safranin in a concentrated chloral hydrate solution; and the surplus stain having been washed out in distilled water, the leaf was bleached in chloral hydrate solution until just the vascular system retained the red color. The leaf venation is very irregular and does not form a close network. In each lobe of the leaf a main branch of the vascular system finds its termination (fig. 83).

The venation of the leaf ends blindly throughout the mesophyll (fig. 84), except at the edge of the leaf, where the ultimate endings are groups of tracheids extending out close to the epidermis (fig. 85). The ultimate endings of the venation stand on an average of .9 mm. apart in the greater part of the mesophyll of the leaf, but the tracheid endings at the edge of the leaf stand

about .5 mm. apart. The tracheids are of three kinds, spiral, annular, and reticulate (figs. 84, *p''*, *q''*, and *r''*; and 85, *p''*, *q''*, and *r''*).

The xylem, phloëm and border parenchyma cells of a vascular bundle of the leaf are shown in cross section in fig. 72. The border parenchyma cells in leaves, which were left in 5 per cent potassium hydroxide solution for bleaching, are shown in tangential section in fig. 79. The pits in the end walls of these elongated cells are not conspicuous in unbleached sections (fig. 86).

The vascular system of the petiole is made up of separate vascular strands. This is shown in the cross section of a petiole from the base upward in figs. 87 to 89, inclusive, in which the five vascular strands are mapped out. The cross section of the petiole in fig. 87 was cut from the base of the petiole; fig. 88, midway between the base and tip of the petiole; and fig. 89, from the tip of the petiole. Each vascular strand has a sheath of border parenchyma. A cross section of two of the vascular bundles of the petiole is shown in fig. 90, *j*. Petit (*fide* Solereder, '08) has found that isolated vascular bundles form the vascular system of the petioles in species which he examined in the genera *Artiplex*, *Blitium*, and *Chenopodium*.

In the figs. 91 to 95, inclusive, there is mapped out a series of portions of the cross sections of the stem from below the petiole attachment to a little above. The five leaf-trace bundles are mapped out in fig. 91. In fig. 92 the leaf traces are crossing out of the stem into the petiole. Successive steps in the closing of the leaf gap are shown in figs. 93, 94 and 95.

NATURE OF THE CELL CONTENTS.

The Stem.

Distributed through the protoplasts of the cells of the epidermis, and of the collenchyma and parenchyma of the primary cortex, there are quite a number of large globules (and many small globules) which stain like oil with Sudan III and alcannin (fig. 9, *q'*). Similar globules are present in the cells of the phloëm of primary vascular bundles, and of the phloëm and secondary medullary rays of the anomalous tissue. The globules in newly cut sections of formalin material, left in Sudan III for twenty-four hours, stained red; in alcannin, pink. Some of the globules in sections which had remained in xylene, chloroform or ether for twenty-four hours, and were then left in either of the two stains mentioned above, stained as before, but nearly all the globules

had been dissolved out. All the globules which stain like oil dissolved out in sections left in xylene, chloroform or ether for forty-eight hours. Certain of these globules stain evenly, but most of them stain unevenly. Usually a spherical core (ranging from 4 to 20 per cent of the volume of the globule), located in the center or at the side of each unevenly stained globule, stains a darker or lighter red than the rest of the globule. Two separate spherical cores were present in each of certain globules observed.

Saponification tests on fresh sections did not indicate the presence of saponifiable oil in the globules. The Tunmann reagent used for the tests was made up fresh, and was tested on castor-bean sections, the oil of which saponified. The test was repeated on freshly cut sections of stem, and more reagent was made available to the mounted sections by placing small strips of cork at the edge of the cover-slips, which were then sealed with wax (65 per cent beeswax and 35 per cent rosin), or by the use of hollow-ground slides. The slides were placed in the electric oven and examined daily. The globules, which stain like oil, dissolved out in from twenty-four to forty-eight hours, and no saponification was evident in sections examined with the aid of the microscope or polarizer.

The oil globules in sections steamed for eight hours and then left in Sudan III or alcannin for twenty-four hours stained like the globules in sections, newly cut from formalin material, left in either of the two stains for twenty-four hours. Evidently no substance in the globules escapes when the sections are steamed, for the globules average the same size as the globules in sections not steamed. Condensed vapor from steam, which had been passed over sections and then condensed on cold petri dishes, did not stain yellow when exposed to the vapors from heated iodine crystals, and the presence of violatile oil was not demonstrated.

The above tests indicate that an oil is present in the globules, but evidently not a volatile nor a saponifying oil.

In many of the cells containing globules staining like oil there are also greenish-yellow globules, which do not dissolve out after the sections have remained seven days in xylene, chloroform or ether, and which do not stain when the sections are left in Sudan III or alcannin for forty-eight hours (fig. 9, *r'*). These globules were tested for glucosides as follows: Sections were boiled in 5 cc. of Fehling's solution, and at first there was no change in the color of the reagent, nor could crystals of cuprous oxide be seen in these yellowish-green globules with the microscope; a precipi-

tate of cuprous oxide began to form after boiling for a minute or so; and upon further boiling a copious precipitate formed. Other sections mounted in Fehling's solution on hollow-ground slides were placed in the electric oven and examined daily. After twenty-four hours cuprous oxide crystals had formed, and for three days thereafter the number of crystals gradually increased and the globules disappeared. The slow reduction of two tests suggest the presence of glucosides in these globules.

The presence of resin was not indicated in sections which had been left in concentrated copper acetate solution for three weeks.

The blue stain characteristic of mucilage did not develop in free-hand sections placed in a solution of methylene blue in equal parts of alcohol, glycerine and water.

Tannin was not demonstrated in sections mounted in ferric chloride.

A few crystals of cuprous oxide were formed in the cells of the epidermis, and also in cells of the collenchyma, parenchyma, and starch sheath of the primary cortex, in sections mounted in Fehling's solution and heated just to the boiling point. Crystals of cuprous oxide were also formed in the phloëm cells of the primary vascular bundles. The presence of reducing sugar, probably grape sugar, was thus indicated by the immediate reduction of the reagent without boiling.

Starch was not generally found in the starch sheath; a slight amount of starch was found in region II; a few cells of the starch sheath in the main axis of the stem contained much starch.

The contents of cells of the phloëm of the primary vascular bundles and the phloëm of the anomalous tissue stain red in sections left in Millon's reagent for several hours in the electric oven. A yellow stain of these cell contents appeared in sections mounted in concentrated nitric acid, and the yellow color deepened when a drop of ammonium was added. The results of the two tests indicate the presence of proteins.

Large spherical aggregates of calcium oxalate crystals are present in the starch sheath cells, in the outer rows of cells of the pericycle, and in the pith cells, in all regions of stem; but are especially abundant in region III and below (fig. 9, *s*). The starch sheath cells and a few collenchyma cells of the primary cortex in region II are filled with masses of the crystals. Only one aggregate of crystals occurs in a single cell. A few of the pith cells in regions III and IV and the main axis contain a few or quite a number of single crystals (fig. 9, *t*). There are abundant clusters of these

crystals in the secondary medullary rays and pericycle cells in the zones of thin-walled anomalous tissue (designated as phloëm zones in this article). When sections mounted in distilled water on a slide were irrigated with a drop of hydrochloric acid, the crystals disappeared in several seconds without effervescence, indicating the presence of calcium oxalate. Jost ('08) states, many plants normally containing calcium oxalate have only a small amount or none present, when presented with not more than the indispensable minimum of $Ca(NO_3)_2$, according to Amar; or if presented with nitric acid in the form of an ammonium salt, according to Beneck. It is of interest to note here that Politis (*fide* Experiment Station Record, '12) draws the following conclusions from his research work on the origin and office of oxalate of lime in plants: "Oxalic acid, with its resulting calcium oxalate, has its origin in the cell in which the salt is found in crystalline form, and the acid is formed by oxidation of glycogen or amyloids."

Free-hand sections over one cell in thickness were tested for alkaloids, and sections soaked in an alkaloid solvent (one part of tartaric acid dissolved in twenty parts of alcohol for twenty-four hours and rinsed in distilled water for twenty-four hours were used as a control. No precipitate formed in sections mounted in potassium iodide-iodine, potassium permanganate, or ammonium molybdate. Sections were treated with picric acid and tannic acid, as suggested by Winterstein and Trier ('10), but no precipitate formed. No characteristic color developed with nitric acid or sulphuric acid to indicate the presence of alkaloids. No precipitations or color reactions occurred in the control sections treated with tartaric alcohol, nor was there any marked indication that cell contents had been dissolved out.

The Root.

Tests were made on the sections of the root as on the sections of the stem. Globules in the cells of the epidermis and primary cortex dissolved out in xylene or chloroform, and the globules of other sections stained red in Sudan III and pink in alcannin. The globules did not give a test for saponifying oil nor resin. A slight amount of reducing sugar was found in the cells of the pericycle, the phloëm and xylem parenchyma of the primary vascular bundles, and the secondary medullary rays and phloëm of the anomalous tissue. The presence of protein was indicated in the cell contents of the phloëm of the primary vascular bundles and the phloëm of the anomalous tissue by the red stain with Millon's

reagent. The characteristic yellow stain deepened when a drop of ammonium was added to sections which had been mounted in nitric acid. Clusters of crystals of calcium oxalate were numerous in the cells of the primary cortex, the pericycle, and the secondary medullary rays. No volatile oil, glucosides, mucilage, tannin, starch nor alkaloids were found to be present in the root.

The Leaf.

Similar tests were made on sections of the leaf. Certain globules which stain red in Sudan III and pink in alcannin, like oil, were present in the cells of the epidermis, and photosynthetic tissue (fig. 73, *q'*). These globules stain unevenly like similar globules in the stem. The globules are soluble in xylene, chloroform, and ether. Other tests did not indicate the presence of saponifying oil nor resin in these globules.

There are other globules, most of which are quite large, in the epidermal cells, which did not stain with Sudan III nor alcannin, and which were not soluble in xylene, chloroform, nor ether; but these globules in sections left in the electric oven formed crystals of cuprous oxide with Fehling's solution continuously for three days, the presence of glucosides thus being indicated (fig. 73, *r'*).

The presence of reducing sugar was demonstrated by the formation of cuprous oxide crystals in the cells of the phloëm and photosynthetic tissue when sections of the leaf in Fehling's solution were heated to the boiling point.

The characteristic stain of protein developed with Millon's reagent, or nitric acid with the addition of ammonium, in the cell contents of the phloëm of leaf sections tested.

Clusters of calcium oxalate crystals occur in great abundance in the border parenchyma cells of the veins, and the water-storage tissue. In a general drawing of a bleached leaf, the greater part of the leaf is darkened by the numerous crystals mapped out along the veins and veinlets of the leaf (fig. 96).

The other tests applied did not indicate the presence of volatile oil, mucilage, tannin, starch nor alkaloids in the leaf.

The Hairs of the Leaf and Stem.

In the cells of the basal portions of the clothing hairs (figs. 16, *q'*, and 77, *c''*,) and of the glandular hairs (figs. 17, *q'*, and 78, *c''*) of the stem and the leaf are globules which stain with Sudan III and alcannin.

There are more of such globules in the four cells of the terminal portion (figs. 17, *u'*, and 78, *u'*) of the glandular hairs than in the basal portion (figs. 17, *u'*, and 78, *u'*). In the terminal cell, and the cell just beneath, in certain of the glandular hairs are a few very large oil globules (fig. 78, *d''*) some of which have a volume thirty-six times as great as the other oil globules. The usual tests do not indicate the presence of saponifying oil, volatile oil nor resin in these globules. The cell contents of the terminal portion of the glandular hairs appear yellow in formalin material. In iodine solution, potassium iodide-iodine or chloroiodide of zinc a portion of these cell contents stain dark blue. The stain with iodine solution thus indicates the presence of starch.

The cell contents of the terminal portion of the glandular hairs did not dissolve out in 5 per cent potassium hydroxide in twenty-four hours or one week. After remaining twenty-four hours in concentrated potassium hydroxide solution all the oil globules and most of the cell contents had been dissolved out. Portions of the cell contents dissolved out in 10 per cent nitric acid and 10 per cent sulphuric acid. In concentrated sulphuric acid the cell contents are stained orange, and a part of the cell contents are dissolved out after 15 minutes. A part of the cell contents are dissolved out in 15 minutes in sections treated with concentrated nitric acid, but the cell contents do not change in color in this strength of the acid. Apparently only the oil globules are removed from hairs remaining in xylene, chloroform or ether for twenty-four hours or one week. The cell contents stain with safranin, and portions also stain with hæmatoxylin.

Some reducing sugar was present in the cells of the basal portions of both the clothing and glandular hairs.

The presence of glucosides, mucilage, tannin, protein, calcium oxalate or alkaloids was not demonstrated in either of the two types of hairs.

BOTANICAL LABORATORY,
UNIVERSITY OF KANSAS.

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DESCRIPTION OF PLATES.

PLATE I.

FIG. 1. A photograph of a main branchlet, showing the small leaves and the habit of branching.

PLATE II.

FIG. 2. Cross section of the stem in region I. (See fig. 29, *m''*); *a*, epidermis; *b*, collenchyma of primary cortex; *c*, parenchyma of primary cortex; *d*, starch sheath between the dotted and continuous line; *e*, outer area of the pericycle made up of small cells; *f*, inner area of the pericycle made up of large cells; *g*, primary medullary ray; *h*, pith; *i*, hair; *j*, primary vascular bundle. × 48.

FIG. 3. Cross section of the stem in region II. (See fig. 29, *o''*.) The woody cylinder is colored black, and the included phloëm groups and larger tracheæ are left white. The cell walls are cellulose in the area *e''*, which is the outer portion of the pericycle area *e*, and are lignified in the inner portion *e''*, of the pericycle area *e*. Corresponding parts lettered as in fig. 2: *k*, leaf-trace bundle in the pericycle. × 48.

FIG. 4. Cross section of the stem in region III. (See fig. 29, *p''*). The woody cylinder is colored black, and the included phloëm groups and larger tracheæ are left white. Corresponding parts lettered as in fig. 2: *b*, leaf-trace bundle; *l*, inner border of the innermost anomalous xylem ring; *m*, anomalous xylem; *n*, active arc of secondary meristem. × 30.

FIG. 5. Cross section of the stem in region IV. (See fig. 29, *r''*.) The cell walls of the primary medullary rays, and regions *e''* and *f*, of the pericycle in this section, are not lignified except in the outer portion of the pericycle area *e''* (this outer portion of *e''*, colored black, being included in the

woody cylinder). Corresponding parts lettered as in figs. 2 and 4: *n*, one of the several active arcs of secondary meristem in the figure which anastomose radially and tangentially with the arcs, in the corresponding ring of secondary arcs, in the region of stem below; *o*, area of one to six rows of very large parenchyma cells of the primary cortex around the stem; *p*, anomalous zylem zone; *q*, zone of anomalous tissue, designated as a phloëm zone in this article; *r*, secondary medullary ray; *s*, anomalous phloëm; *t*, pericycle cells in outer portion of a zone of anomalous tissue, designated as a phloëm zone in this article. × 18.

PLATE III.

FIG. 6. Cross section of the stem in region V. (See fig. 29, *s''*.) Corresponding parts lettered as in fig. 5: *u*, radial strip of xylem anastomosing from one anomalous xylem zone to another; *a*, lenticel; *b'*, cork; *c'*, xylem, the cell walls of which are not lignified except those of the tracheæ included in the innermost anomalous xylem zone; *d'*, xylem of usual structure included in the innermost xylem zone; *f'*, bast fiber; *g'*, radial strip of tissue anastomosing from one phloëm zone to another. × 9.

FIG. 7. Cross section of the stem in region I. (See fig. 29, *m''*.) Corresponding parts lettered as in fig. 2: *h'*, phloëm of primary vascular bundle; *i'*, procambium of primary vascular bundle; *j'*, primary xylem of primary vascular bundle; *k'*, cuticle; *l'*, chloroplast. × 225.

FIG. 8. Cross section of the stem in region II. (See fig. 29, *o''*.) Corresponding parts lettered as in figs. 2 to 7, inclusive: *m'*, secondary phloëm of primary vascular bundle; *n'*, cambial layer of primary vascular bundle; *o'*, secondary xylem of primary vascular bundle; *p'*, intercellular space. × 225.

PLATE IV.

FIG. 9. Cross section of the stem in region III. (See fig. 29, *p''*.) Corresponding parts lettered as in fig. 8: *k*, parenchyma of primary cortex between collenchyma of the rib and the starch sheath; *q'*, oil globule; *r'*, glucoside globule; *s'*, mass of calcium oxalate crystals in a pith cell; *t'*, single crystals of calcium oxalate in a pith cell. × 225.

FIG. 10. Outer portion of cross section of the stem in region IV. (See fig. 29, *r''*.) Corresponding parts lettered as in fig. 8: *o*, area of one to six rows of very large parenchyma cells of the primary cortex around the stem; *p*, anomalous xylem zone; *q*, anomalous phloëm zone; *r*, secondary medullary ray; *s*, anomalous phloëm; *t*, pericycle cells in the outer area of a zone of anomalous tissue, designated as a phloëm zone in this article; *u*, radial strip of xylem anastomosing from one anomalous xylem zone to another. × 225.

PLATE V.

FIG. 11. Inner portion of a cross section of the stem in region IV. (See fig. 29, *r''*.) Corresponding parts lettered as in fig. 8. × 225.

FIG. 12. Surface view of lengthened epidermal cells of a rib of the stem in region III, showing type and frequency of stomata. × 225.

FIG. 13. Radial longitudinal section of the epidermis of the stem in region III: *k'*, cuticle. × 225.

FIG. 14. Surface view of the epidermal cells between the ribs of the stem in region III, showing type and frequency of stomata. × 225.

FIG. 15. Portion of radial longitudinal section of the stem in region III, showing epidermis, *a*, the parenchyma of the primary cortex, *e*, and the starch sheath, *d*: *k'*, cuticle; *p'*, intercellular space. × 225.

FIG. 16. Clothing hair of the epidermis of the stem in region I: *a*, basal cell; *k'*, cuticle; *q'*, oil globule; *u'*, terminal portion; *a''*, basal portion of one or more short cells above the basal cell. × 330.

FIG. 17. Glandular hair of the epidermis of the stem in region I: *a*, basal cell; *k'* cuticle; *u'*, terminal portion; *a''*, basal portion consisting of two or more short cells; *b''*, dense cell contents in terminal portion; *c''*, small oil globule; *d''*, large oil globule. × 225.

FIG. 18. Longitudinal section of the collenchyma of the primary cortex of the stem in region III. × 225.

FIG. 19. Portion of cross section of the stem in region V, showing cork cells, *b'*: *d*, starch sheath; *o*, area of one to six rows of very large parenchyma cells of the primary cortex around the stem; *q'*, bast fiber. × 225.

FIG. 20. Portion of cross section of the stem in region V, showing lenticel, *b'*: *a*, epidermis; *c*, parenchyma of the primary cortex; *d*, starch sheath; *o*, area of one of six rows of very large parenchyma cells of the primary cortex around the stem; *f'*, bast fiber; *k'*, cuticle; *p'*, intercellular space; *f''*, stoma. × 225.

PLATE VI.

FIG. 21. Portion of longitudinal section of the stem in region III: *d*, starch sheath; *e'*, outer portion of the pericycle, the cell walls of which have not lignified, corresponding to the area of pericycle *e'* in cross section, fig. 9. × 225.

FIG. 22. Portion of cross section of the stem in region V to show veriation in location of bast fibers in the pericycle: *d*, starch sheath; *o*, portion of area of one to six rows of very large parenchyma cells of the primary cortex around the stem; *f'*, bast fibers; *e'*, outer area of the pericycle, the cell walls of this area not having lignified. × 225.

FIG. 23. Longitudinal section of bast fiber of medium length, from the outer portion of the pericycle of the stem in region IV, corresponding in location to the area of pericycle *e'* in cross section, fig. 9. × 225.

FIG. 24. Macerated wood fibers of medium size from the anomalous xylem of the stem in region IV. × 225.

FIG. 25. Longitudinal section of cells in the central portion of the pericycle from region III of the stem, corresponding to the area of pericycle, *e''*, fig. 10, in region IV. × 225.

FIG. 26. Portion of cross section of the stem in region V, showing the areas of pericycle *e''* and *f*, and cells of the inner portion of the anomalous xylem zone, *c'*, the cells of which in this region of stem resemble pith in shape in cross section: *q*, tissue designated as an anomalous phloëm zone in this article; *r*, secondary medullary ray; *s*, anomalous phloëm; *t*, pericycle cells in the outer part of the tissue designated as an anomalous phloëm zone in this article; *c'*, anomalous xylem having cellulose walls and located in the

innermost anomalous xylem zone; *d'*, anomalous xylem of the usual structure in the outer portion of the innermost anomalous xylem zone. × 225.

FIG. 27. Longitudinal section of primary medullary ray cells from region III of the stem. × 225.

FIG. 28. Longitudinal section of pith cells from region III of the stem. × 225.

PLATE VII.

FIG. 29. Diagram of a longitudinal section of the main axis of the stem to show the location of the five regions of stem, the broken leaf traces of region V and below, and the anomalous xylem-phloëm zones; *j*, primary vascular bundle; *n*, arcs of secondary meristem anastomosing radially with the arcs, in the corresponding ring of secondary arcs, in the region of stem below; *p*, anomalous xylem zone; *q*, tissue designated in this article as an anomalous phloëm zone; *u*, radial strip of xylem anastomosing from one anomalous xylem zone to another; *g'*, radial strip of tissue anastomosing from one anomalous phloëm zone to another; *h''*, fruit; *i''*, leaf; *j''*, branch; *k''*, region of primordial meristem; *l''*, procambium; *m''*, region I; *n''*, region of the stem for fig. 31; *o''*, region I; *p''*, region III; *q''*, region of the stem for figs. 50 and 51; *r''*, region IV; *s''*, region V; *t''*, leaf trace of leaf retained; *u''*, broken leaf trace.

FIG. 30. Primary vascular bundle in the formation in region I of the stem: *f*, inner area of pericycle; *g*, primary medullary ray; *h*, pith; *h'*, primary phloëm; *i'*, procambium; *j'*, primary xylem; *a'''*, water tube.

FIG. 31. Cross section of the stem just below region I (location shown in fig. 29, *n''*), showing young leaf trace bundle, *k*, in pericycle. Corresponding parts lettered as in fig. 8. × 225.

FIG. 32. Primary vascular bundle with cambial layer from region II of the stem. Corresponding parts lettered as in fig. 8. × 330.

FIG. 33. Longitudinal section of sieve tubes from secondary phloëm of primary vascular bundle in region III of the stem. × 330.

FIG. 34. Longitudinal section of companion cells, *b'''*, and phloëm parenchyma *c'''*, of a primary vascular bundle in region III of the stem. × 330.

FIG. 35. Primary vascular bundle, in which the cambial layer is no longer active, in region III of the stem. Corresponding parts lettered as in fig. 32: *d'''*, sieve tube having thickened cell walls; *f'''*, sieve tube with cell walls not thickened. × 330.

FIG. 36. Longitudinal section of a small spiral tracheal tube from primary xylem in region III of the stem. × 225.

FIG. 37. Longitudinal section of larger spiral tracheal tube from primary xylem in region III of the stem. × 225.

FIG. 38. Longitudinal section of annular tracheal tube of medium size from primary xylem in region III of the stem. × 225.

FIG. 39. Longitudinal section of pitted tracheal tube of medium size from a primary vascular bundle in region III of the stem. × 225.

FIG. 40. Longitudinal section of reticulate tracheal tube of medium size from a primary vascular bundle in region III of the stem. × 225.

FIG. 41. Longitudinal section of wood parenchyma from secondary xylem of primary vascular bundle in region III of the stem. × 225.

FIG. 42. Longitudinal section of pitted fiber tracheids from the secondary xylem of a primary vascular bundle in region III of the stem. × 225.

PLATE VIII.

FIG. 43. Primary vascular bundle from region IV of the stem. Corresponding parts lettered as in fig. 32. × 330.

FIG. 44. Older leaf-trace bundle in the pericycle of the stem in region IV. Corresponding parts lettered as in fig. 32. × 330.

FIG. 45. Portion of cross section of the stem in region V, showing primary medullary ray cells which, in this region of stem and below, resemble pith cells in shape and nature of cell walls: *j*, portion of primary vascular bundle. × 225.

FIG. 46. Longitudinal section of cells in a portion of the pericycle of the stem in region III corresponding in location to the area of pericycle *e''*, fig. 9. × 225.

FIG. 47. Portion of a cross section of the stem in region III: *d*, starch sheath; *e'*, outer area of pericycle; *e''*, central area of the pericycle; *n*, active arc of secondary meristem; *f'*, bast fiber. × 330.

FIG. 48. Portion of a cross section of the stem in region III; *d*, starch sheath; *e'*, outer area of the pericycle; *e''*, central area of the pericycle; *k*, leaf-trace bundle in the pericycle; *n*, active arc of secondary meristem. × 330.

FIG. 49. Portion of a cross section of the stem in region III: *d*, starch sheath; *e'*, outer area of the pericycle; *e''*, central area of the pericycle; *f*, inner area of the pericycle; *m*, anomalous xylem; *n*, active arc of secondary meristem; *s*, anomalous phloëm. × 330.

PLATE IX.

FIG. 50. Cross section of the stem between regions III and IV (location shown in fig. 29, *q''*). Corresponding parts lettered as in fig. 6: *l*, inner border of innermost anomalous xylem zone. × 48.

FIG. 51. Cross section of the stem between regions III and IV (location shown in fig. 29, *q''*). Corresponding parts lettered as in fig. 2: *j*, primary vascular bundle; *o*, portion of area of one to six rows of very large parenchyma cells of the primary cortex around the stem; *p*, anomalous xylem zone; *q*, anomalous phloëm zone; *r*, secondary medullary ray cell; *s*, anomalous phloëm; *t*, pericycle cells in outer part of area of tissue designated in this article as an anomalous phloëm zone; *u*, radial strip of anomalous xylem located similar to the strip of xylem anastomosing from one anomalous xylem zone to another in fig. 10, *u*; *p'*, intercellular space; *n''*, area of anomalous tissue, including a radial strip of anomalous xylem and an anomalous phloëm group just exterior; *o''*, long radial strip of anomalous xylem; *p''*, area of anomalous tissue, including a radial strip of anomalous xylem and a secondary medullary ray between the anomalous phloëm groups. × 225.

FIG. 52. Portion of cross section of stem in region IV; to show arc of secondary meristem, *n*, becoming active to form the fourth xylem-phloëm

zone; *d*, starch sheath; *s*, anomalous phloëm; *e'*, outer area of the pericycle; *p*, anomalous xylem zone; *f'*, bast fiber. × 330.

FIG. 53. Portion of a cross section of stem in region V, showing varied structure of the innermost anomalous xylem zone; *p*, anomalous xylem zone; *q*, anomalous phloëm zone; *r*, secondary medullary ray; *s*, anomalous phloëm; *t*, pericycle cells in outer part of area of tissue designated in this article as an anomalous phloëm zone; *m''*, tracheal tube; *n''*, wood parenchyma cell bordering a tracheal tube; *o''*, wood fiber; *p''*, tissue of inner 20 per cent of the anomalous xylem zone, composed entirely of wood fibers; *q''*, tissue of outer 80 per cent of the anomalous xylem zone composed of wood parenchyma and tracheæ. × 225.

FIG. 54. Longitudinal section of cells in the portion of the innermost anomalous xylem zone of the stem in region V, which correspond to the cells in the area, *c'*, fig. 25, but the cells of which have lignified walls and resemble pith cells in shape in cross section. × 225.

FIG. 55. Cross section of cells of anomalous xylem (shown in longitudinal section in fig. 54). × 225.

FIG. 56. Portion of cross section of stem in region V, showing strip of anomalous xylem, *u*, including a water tube, *M''*, and anastomosing from one anomalous xylem zone to another; *p*, anomalous xylem zone; *q*, anomalous phloëm zone; *r*, secondary medullary ray; *s*, anomalous phloëm; *t*, pericycle cells in outer part of tissue designated as a phloëm zone in this article. × 225.

FIG. 57. Portion of cross section of stem in region V, showing portion of the innermost anomalous xylem zone having wood fibers rectangular or almost square and arranged regularly in radial rows: *a'''*, water tube. × 225.

PLATE X.

FIG. 58. Portion of a cross section of the stem in region V, showing *g'''*, radial row of cells, having a radial dimension two to four times as great as their tangential dimension, in the anomalous xylem-phloëm zones. The radial row of cells consists of *h'''*, pericycle cells, and *a'''*, secondary medullary ray cells, in the anomalous phloëm zones; and of *j'''*, cells, which resemble wood parenchyma in size and proportion, in the xylem zones: *p*, anomalous xylem zone; *q*, zone of tissue designated in this article as an anomalous phloëm zone; *r*, secondary medullary ray; *s*, anomalous phloëm; *t*, pericycle cells in outer area of zone of anomalous tissue, designated in this article as a phloëm zone; *u*, radial strip of xylem anastomosing from one anomalous xylem zone to another; *g'*, radial strip of tissue anastomosing from one anomalous phloëm zone to another. × 225.

FIG. 59. Longitudinal section of a portion of pericycle tissue, located in the outer part of a zone of tissue, designated as an anomalous phloëm zone in this article, and corresponding in location to the area of tissue, *t*, in cross section, fig. 57. × 225.

FIG. 60. Longitudinal section of anomalous tissue, corresponding in location to the strip of anomalous tissue, in cross section in fig. 58: *g'''*, radial strip of tissue anastomosing from one anomalous phloëm zone to another. × 225.

FIG. 61. Cross section of the root in region I: *c*, primary cortex; *f*, pericycle; *g*, primary medullary ray; *j*, xylem of primary vascular bundle; *b'*, cork; *m'*, phloëm of primary vascular bundle; *m''*, tracheal tube. × 48.

FIG. 62. Cross section of the root in region II. Corresponding parts lettered as in fig. 61: *p*, anomalous xylem zone; *q*, zone of tissue designated in this article as an anomalous phloëm zone; *r*, secondary medullary ray; *s*, anomalous phloëm; *t*, pericycle cells in outer part of zone of tissue designated in this article as a phloëm zone. × 48.

PLATE XI.

FIG. 63. Cross section of the root in region III. Corresponding parts lettered as in fig. 62: *n*, active arc of secondary meristem. × 48.

FIG. 64. Cross section of the root in region IV. Corresponding parts lettered as in fig. 63: *g'''*, radial row of cells, having a radial dimension two to four times their tangential dimension, in the anomalous xylem-phloëm zones, and having cellulose cell walls. × 30.

PLATE XII.

FIG. 65. Cross section of the root in region V. Corresponding parts lettered as in fig. 64. × 9.

FIG. 66. Cross section of the root in region I. Corresponding parts lettered as in fig. 62. × 225.

FIG. 67. Cross section of the root in region II. Corresponding parts lettered as in fig. 62: *g'''*, radial row of cells, having a radial dimension two to four times as great as their tangential dimension, in the anomalous xylem-phloëm zones.

PLATE XIII.

FIG. 68. Cross section of the root in region III. Corresponding parts lettered as in fig. 62. × 225.

FIG. 69. Cross section of the root in region IV. Corresponding parts lettered as in fig. 62: *m''*, inner 20 per cent of anomalous xylem zone, made up entirely of wood fibers; *n''*, outer 80 per cent of the anomalous xylem zone, of the usual structure found in anomalous xylem zones of the stem. × 225.

FIG. 70. Portion of cross section of the root in region III, showing arc of secondary meristem, *n*, in the pericycle, *f*. × 330.

PLATE XIV.

FIG. 71. Cross section of the leaf mapping out the zones of tissue: *a*, epidermis; *b*, collenchyma; *c*, photosynthetic tissue; *d*, water-storage tissue; *e*, border parenchyma; *f*, vascular elements, *m'''*, lobe of the leaf. × 48.

FIG. 72. Portion of cross section of the leaf through the main rib. Corresponding parts lettered as in fig. 71: *k'*, cuticle: *m'*, phloëm; *o'*, xylem; *p'*, intercellular space; *d'''*, sieve tube having thick walls; *e'''*, palisade layer of the photosynthetic tissue; *m'''*, mesophyll parenchyma just beneath the palisade layer; *n'''*, mesophyll parenchyma located between the water-storage tissue and the lower epidermis. × 330.

PLATE XV.

FIG. 73. Portion of cross section of the leaf, showing structure between the bases of two lobes on one side of the leaf. Corresponding parts lettered as in fig. 72: *q'*, oil globule; *r'*, glucoside globule; *s'*, mass of calcium oxalate crystals in a cell of the water-storage tissue; *f''*, stoma. × 330.

FIG. 74. Surface view of cells of the upper epidermis, showing type and frequency of stomata. × 225.

FIG. 75. Surface view of cells of lower epidermis, showing type and frequency of stomata. × 225.

FIG. 76. Surface view of the lengthened cells of the upper epidermis over the main rib, showing type and frequency of stomata. × 225.

FIG. 77. Clothing hairs of the epidermis of a very young leaf: *a*, basal cell; *k'*, cuticle, *q'*, oil globule; *u'*, terminal portion; *a''*, basal portion of one or more short cells above the basal cell. × 330.

FIG. 78. Glandular hairs of the epidermis of a very young leaf: *a*, basal cell; *k'*, cuticle; *l'*, dense cell, contents in the terminal spherical cell; *u'*, terminal portion; *a''*, basal portion; *c''*, small oil globule; *d''*, large oil globule. × 330.

PLATE XVI.

FIG. 79. Portion of a tangential section of a leaf bleached in 5 per cent potassium hydroxide: *d*, water-storage tissue; *e*, spiral tracheal tube of the vascular elements; *n'''*, border parenchyma cells having end walls pitted. × 330.

FIG. 80. Surface view of a bleached leaf, embracing the epidermal, the palisade and the vascular bundle systems. × 330.

FIG. 81. Portion of a tangential section of the leaf, showing cells of the epidermis, *a*, and mesophyll parenchyma, *n'''*, under the water-storage tissue: *k'*, cuticle; *p'*, intercellular space. × 330.

FIG. 82. Portion of a cross section of the leaf to show collenchyma in the tip of a lobe of the leaf: *a*, epidermis; *b*, collenchyma; *k'*, cuticle; *n'''*, mesophyll parenchyma. × 80.

PLATE XVII.

FIG. 83. Bleached leaf, showing venation: *d*, water-storage tissue between the three largest veins. × 17.5.

FIG. 84. Blind ending of the venation in the midst of the mesophyll, showing spiral, *p''*, annular, *q''*, and reticulate, *r''*, tracheids. × 330.

FIG. 85. Groups of spiral, *p''*, annular, *q''*, and reticulate, *r''*, tracheids, which extend out close to the expidermis and serve as the ultimate endings of the venation at the edge of the leaf. × 330.

FIG. 86. Portion of a tangential section of the leaf to show pits in end walls of border parenchyma cells, *o'''*, are not conspicuous in unbleached sections: *j*, vascular elements. × 330.

FIGS. 87-89. A series of cross sections of the petiole of the leaf proceeding upward: *a*, epidermis; *b*, collenchyma; *e*, photosynthetic tissue; *d*, water-storage tissue; *e*, border parenchyma; *p''*, *q''*, *r''*, *s''*, and *t''*, five vascular bundles of the petiole.

FIG. 87. Cross section from the base of the petiole. × 48.

FIG. 88. Cross section midway between the base and the tip of the petiole. × 48.

FIG. 89. Cross section from the tip of the petiole, showing vascular-bundle strands, *o''* and *u''*, which are branches of *p''* and *t''*, respectively. ×48.

FIG. 90. Portion of a cross section midway between the base and the tip of the petiole, showing two vascular bundles, *j*: *d*, water-storage tissue; *e*, border parenchyma; *d'''*, sieve tube having thick walls. × 330.

PLATE XVIII.

FIGS. 91 to 94, inclusive. A series of cross sections of the stem in region IV, from below the petiole attachment to a little above. The anomalous tissue is colored black.

FIG. 91. Section of the stem just below the petiole attachment, showing the five leaf-trace bundles, *p''*, *q''*, *r''*, *s''* and *t''*, about to enter the petiole. Corresponding parts lettered as in fig. 2. × 48.

FIG. 92. *p''*, *q''*, *r''*, *s''* and *t''* are in the leaf-trace gap, and are entering the petiole. × 48.

FIG. 93. *p''*, *q''*, *r''*, *s''* and *t''* have left the leaf-trace gap, *p'''*. × 48.

FIG. 94. *p'''*, leaf-trace gap partially closed. × 48.

PLATE XIX.

FIG. 95. Leaf-trace gap closed in a section of the stem just above the petiole attachment. × 48.

FIG. 96. General drawing of a leaf, bleached in 5 per cent potassium hydroxide, to show the abundance of calcium oxalate crystals occurring in the border parenchyma of the veins, and the water-storage tissue. The areas colored black represent the location of the masses of crystals.

CYCLOLOMA ATRIPLICIFOLIUM.
D. J. Pratt.

PLATE I.

1

D. J. Pratt.

2

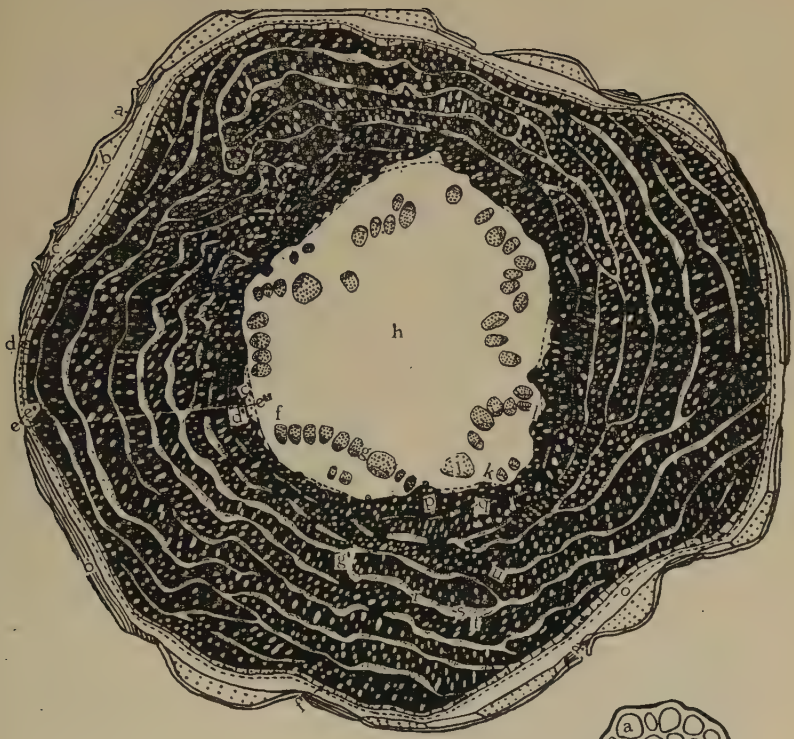
3

4

5

CYCLOLOMA ATRIPLICIFOLIUM. PLATE III.

D. J. Pratt.



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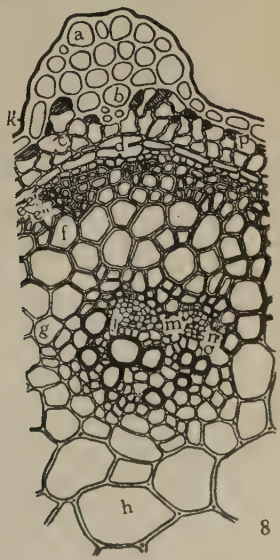

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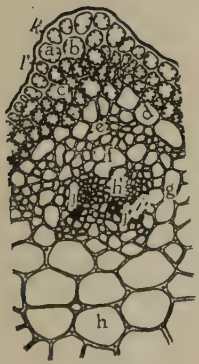

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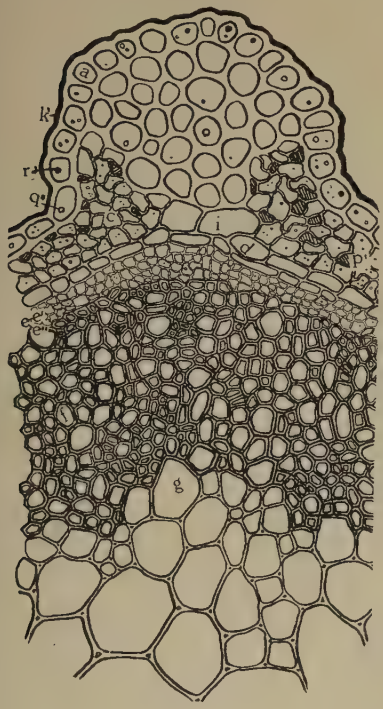
CYCLOLOMA ATRIPLICIFOLIUM.
D. J. Pratt.

PLATE IV.



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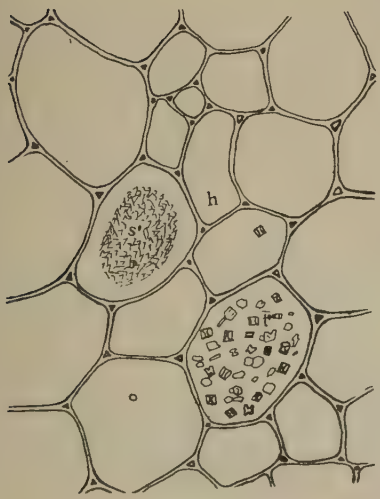

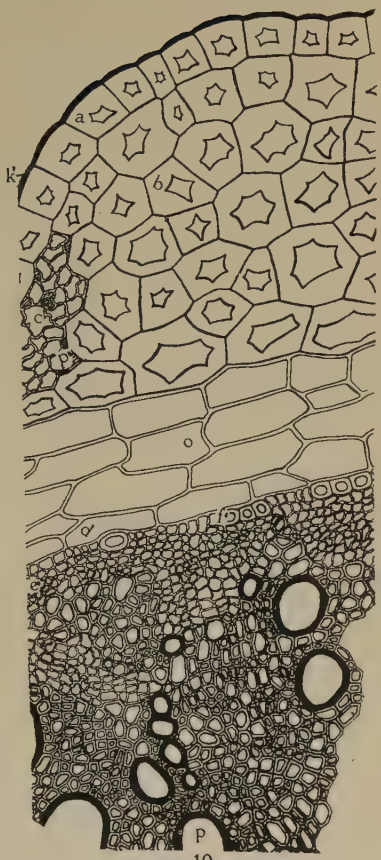

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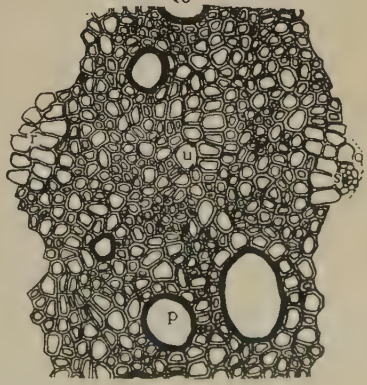

CYCLOLOMA ATRIPLICIFOLIUM.
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PLATE V.

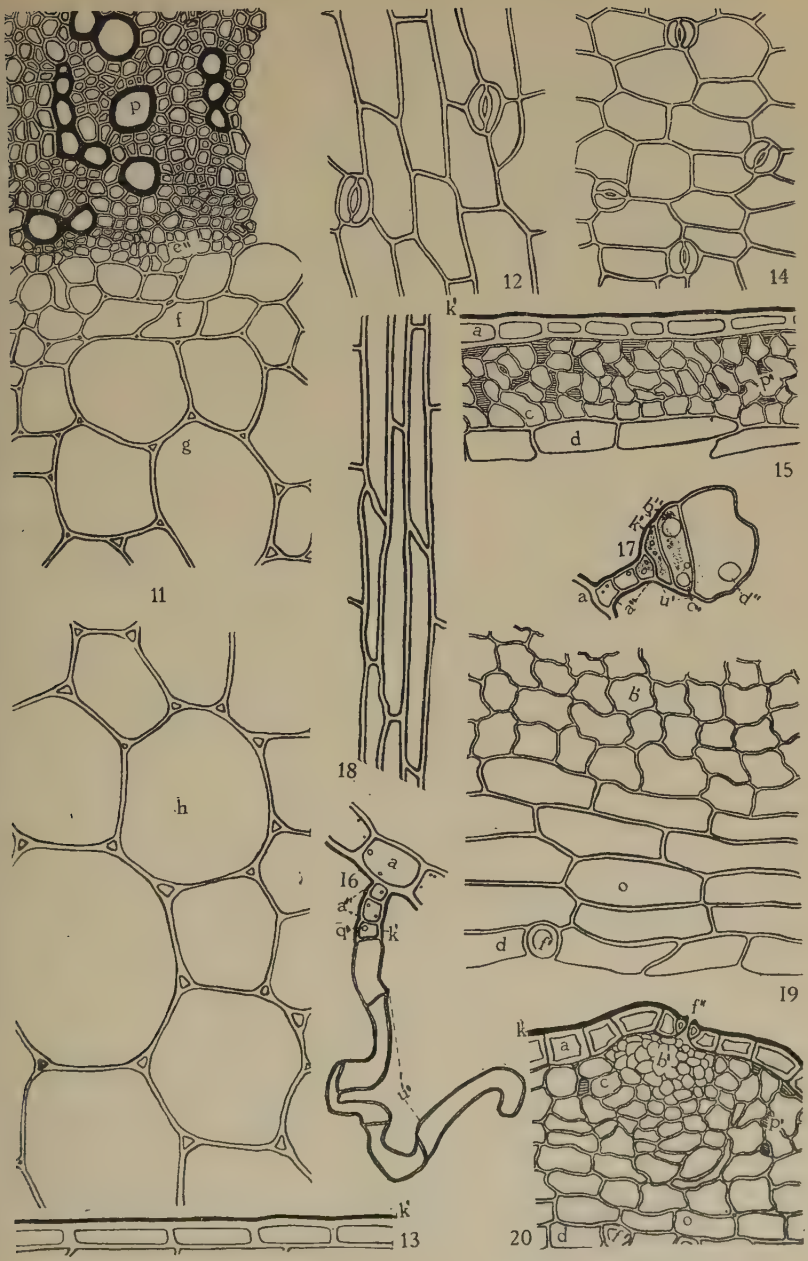

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PLATE VI.

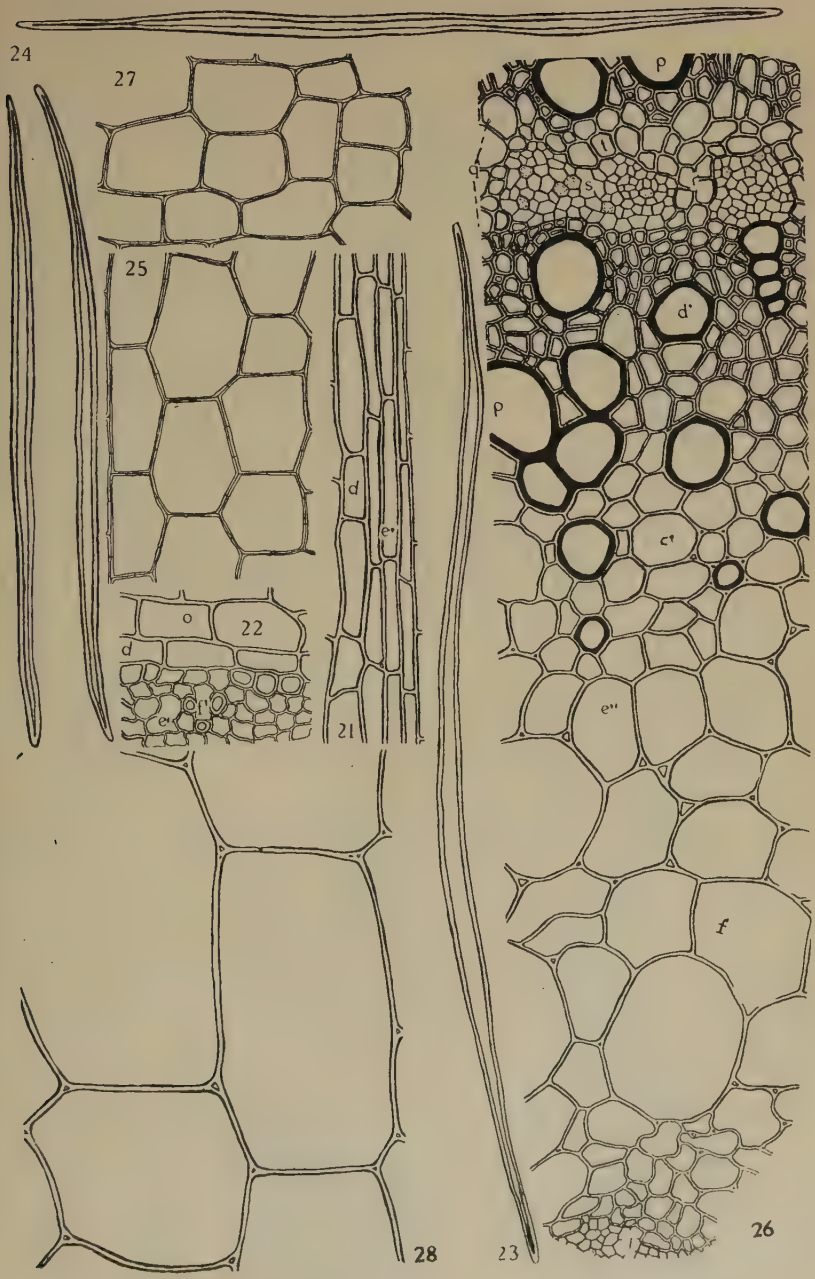

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PLATE VII.

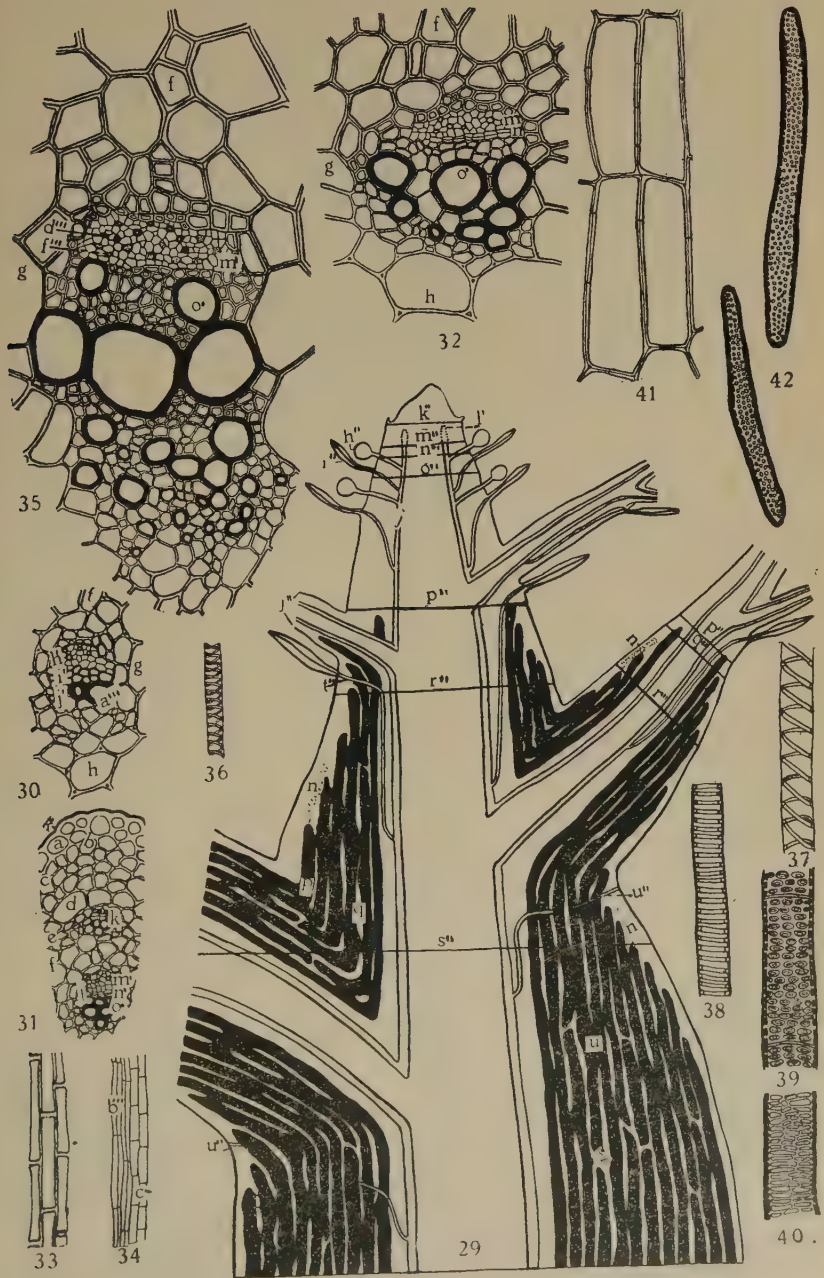

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PLATE VIII.

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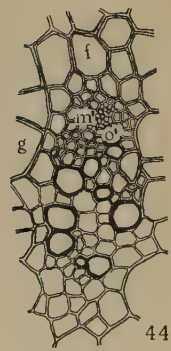

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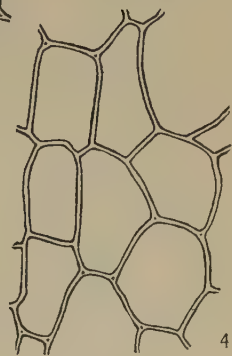
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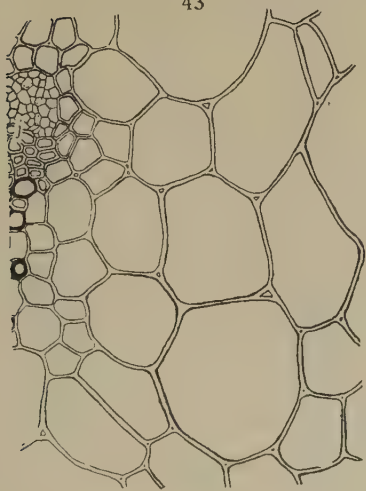
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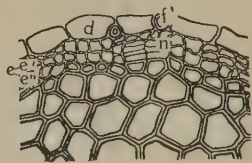

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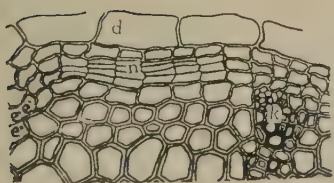

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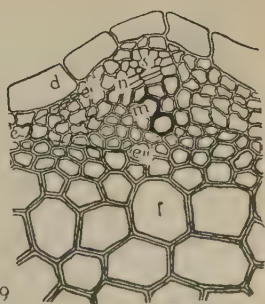

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PLATE IX.

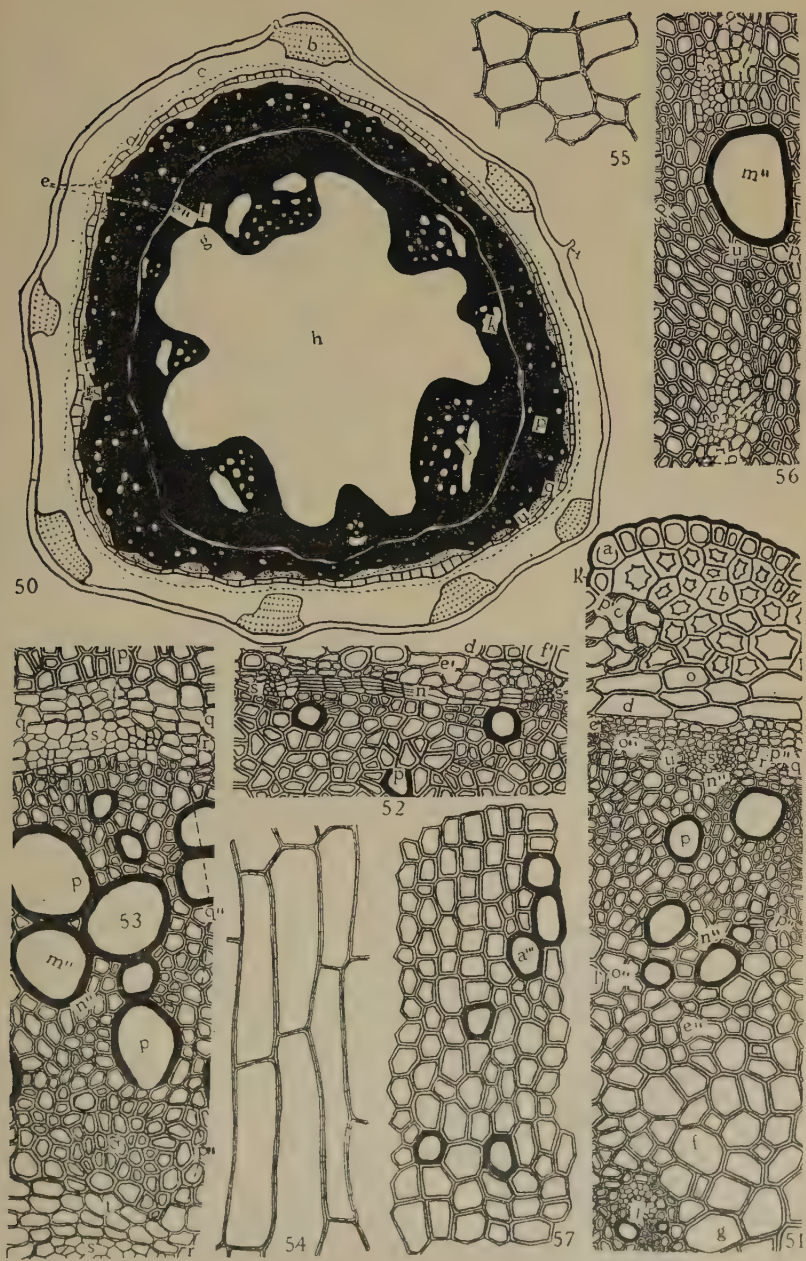

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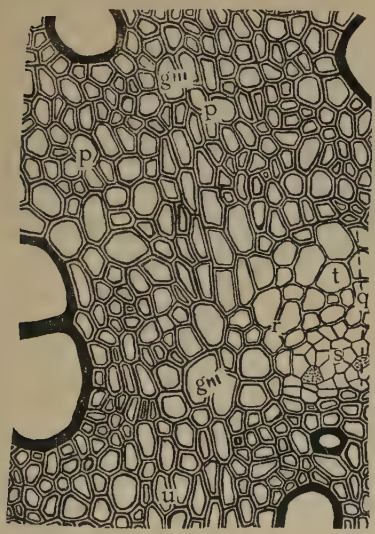
PLATE X.



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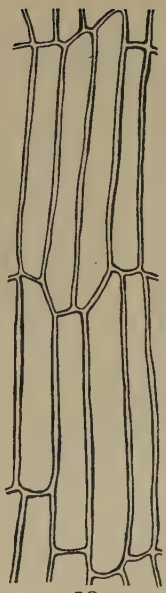

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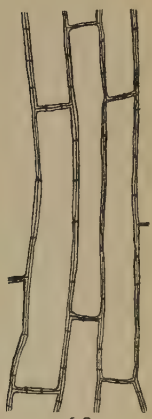

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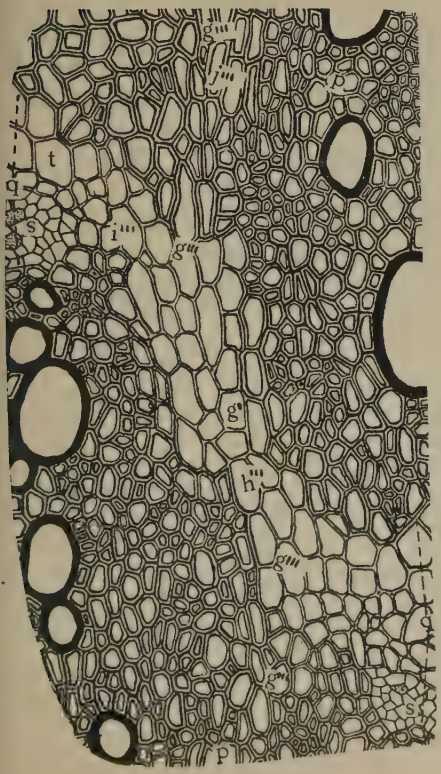

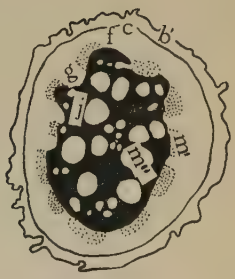

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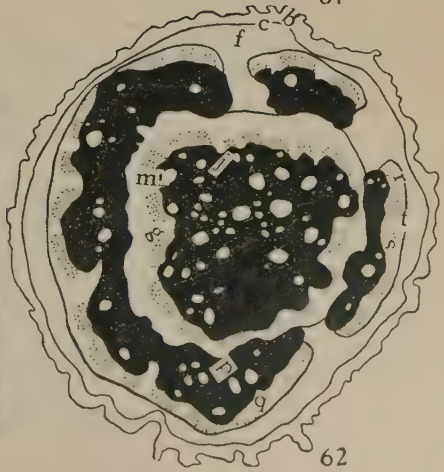

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CYCLOLOMA ATRIPLICIFOLIUM. PLATE XI.

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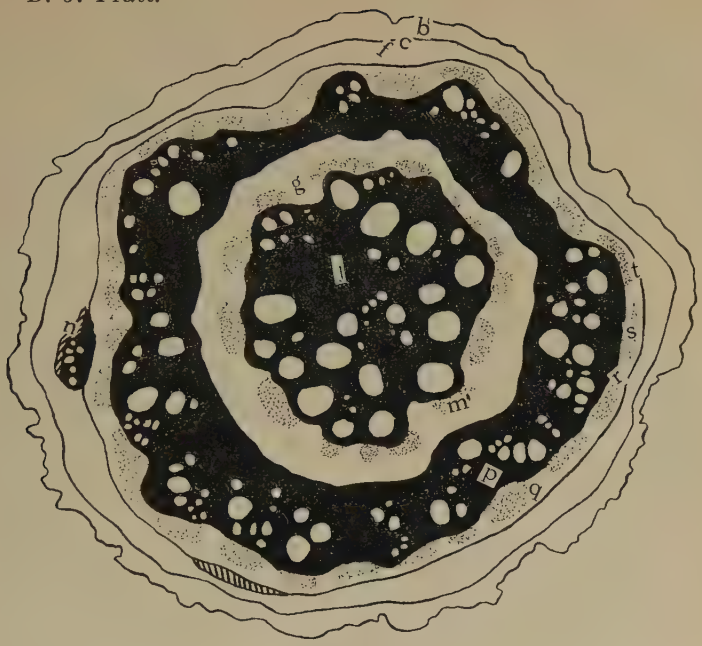

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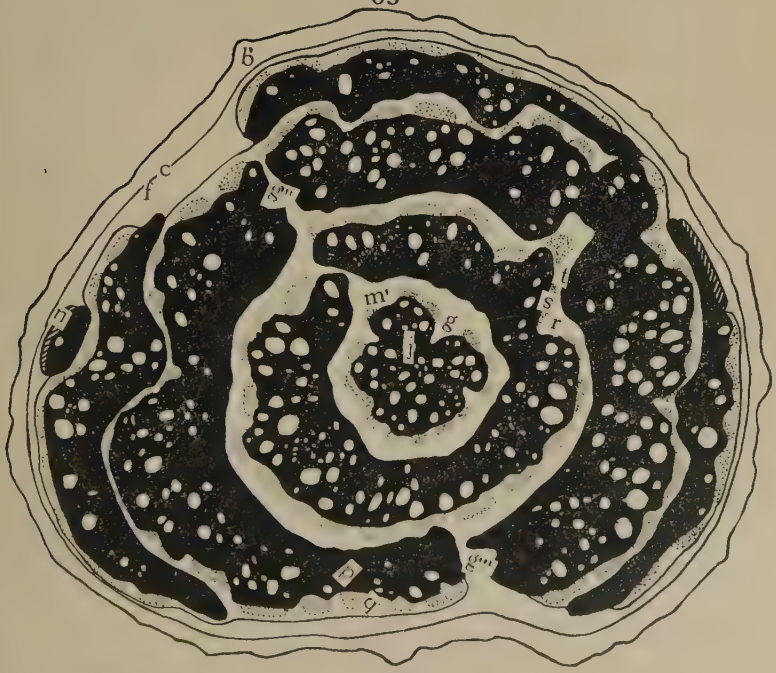

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PLATE XII.

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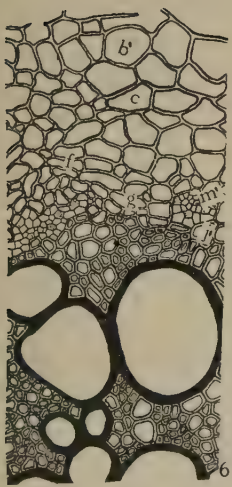

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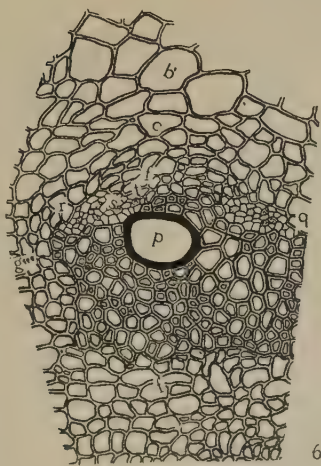

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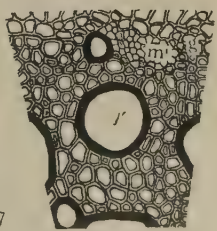

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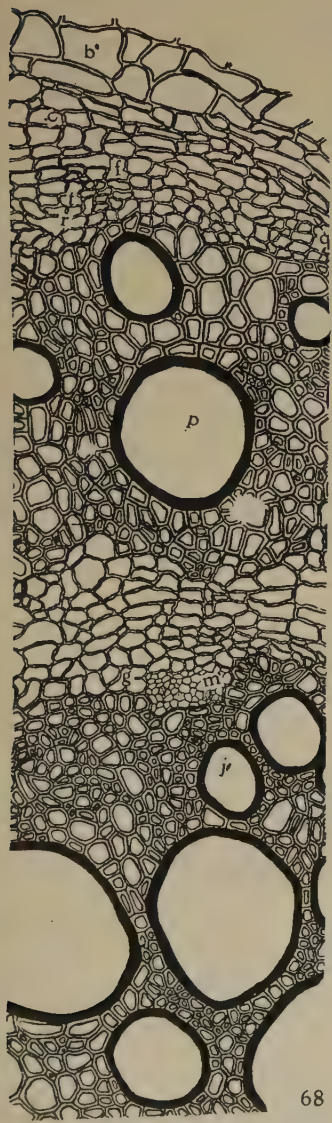
PLATE XIII.



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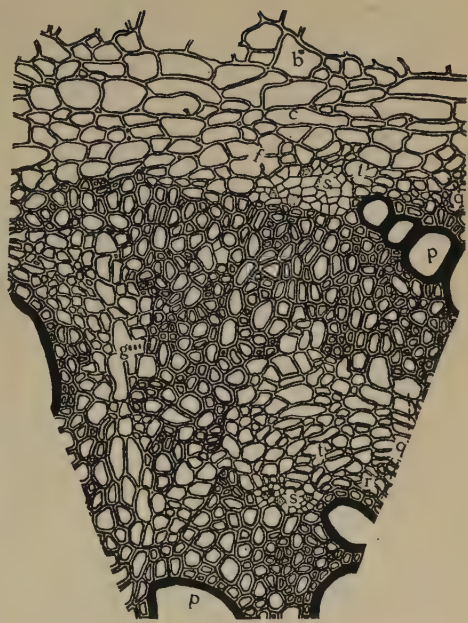

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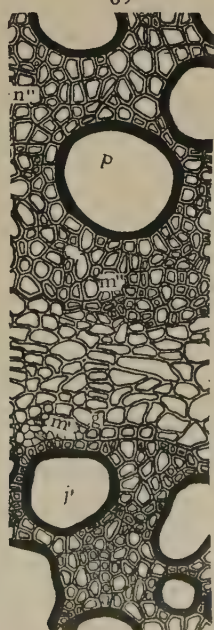

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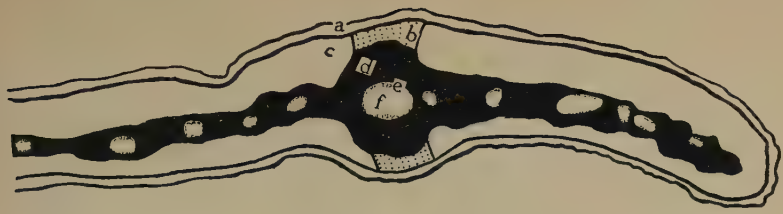
PLATE XIV.



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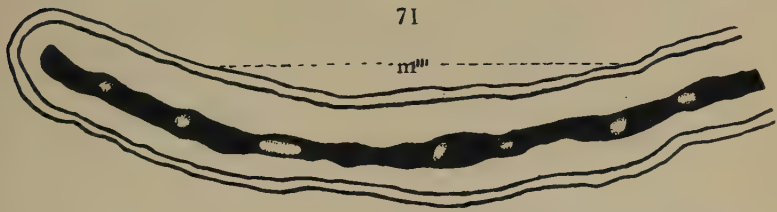

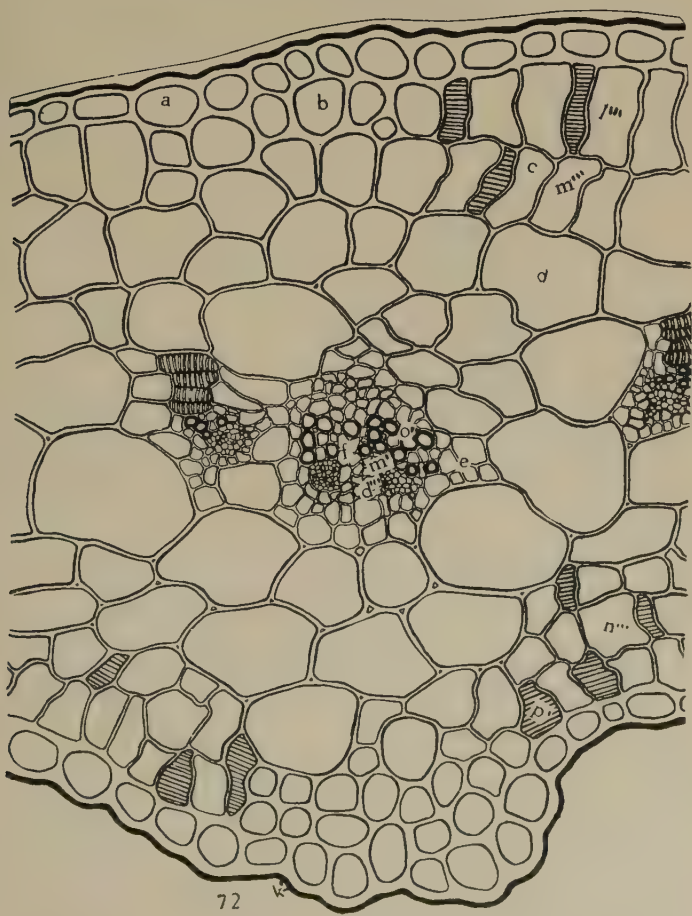

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PLATE XV.

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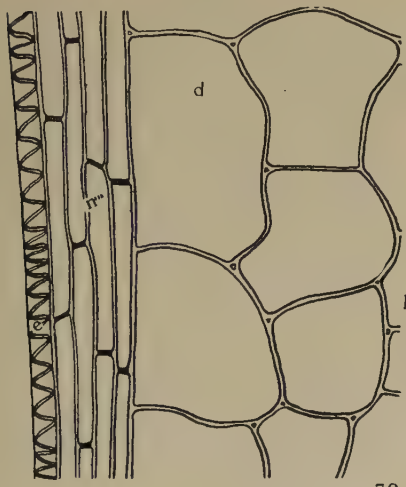
PLATE XVI.



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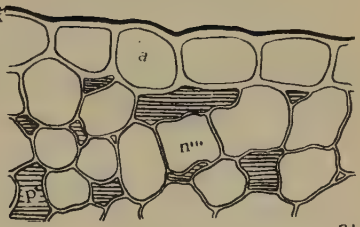

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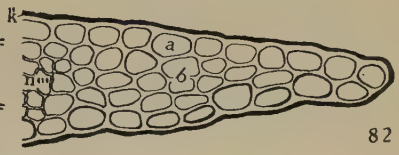

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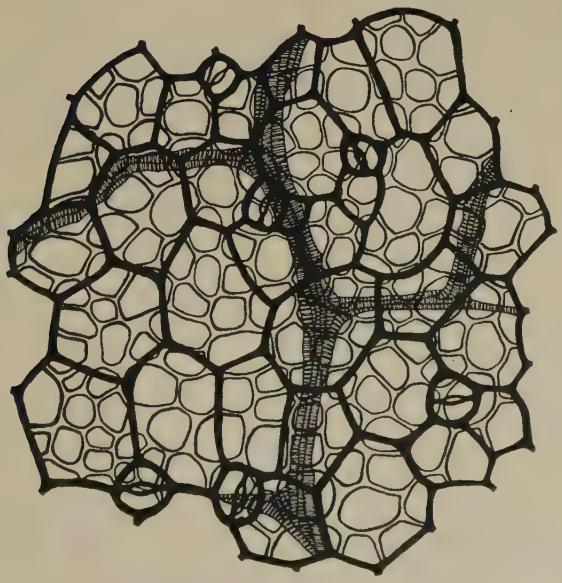

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PLATE XVII.

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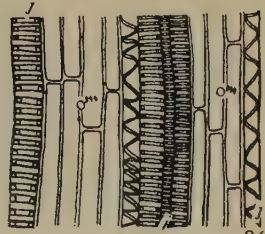

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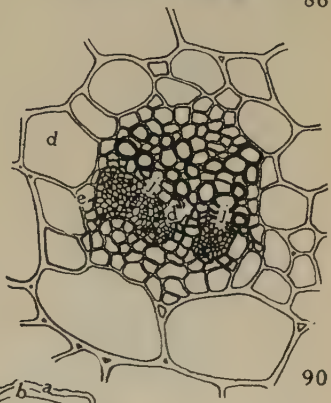

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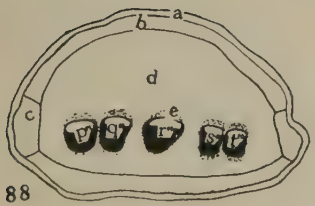

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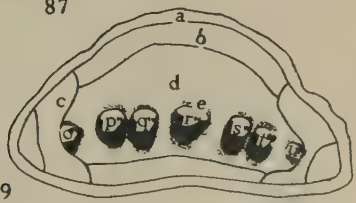

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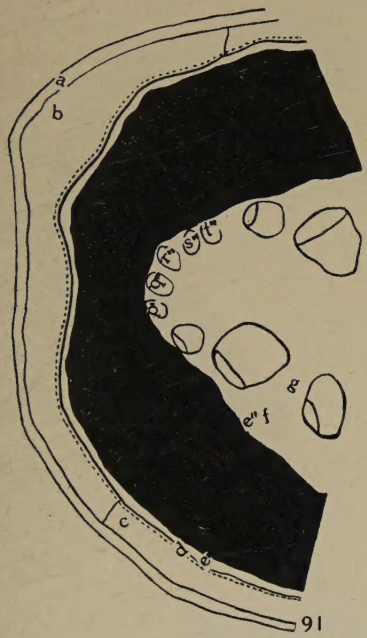
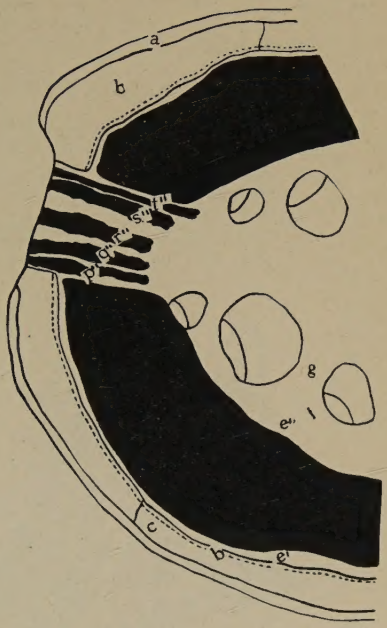
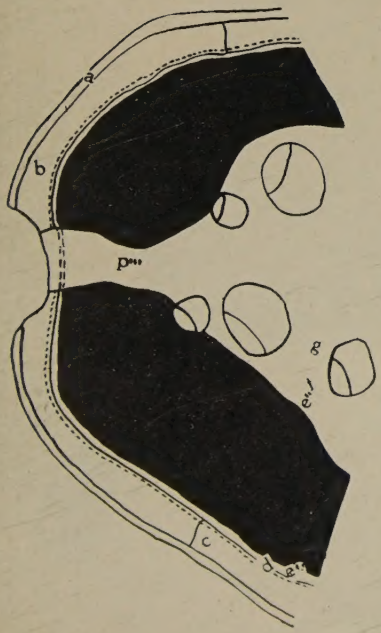
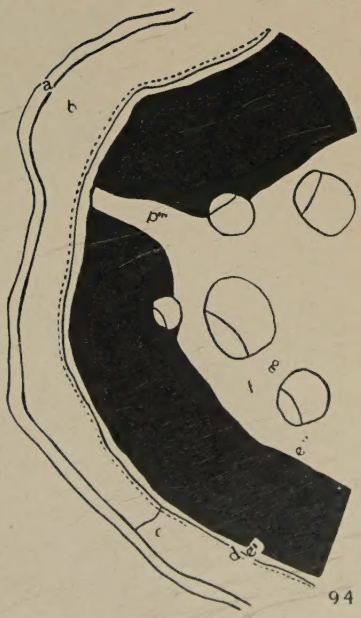
PLATE XVIII.









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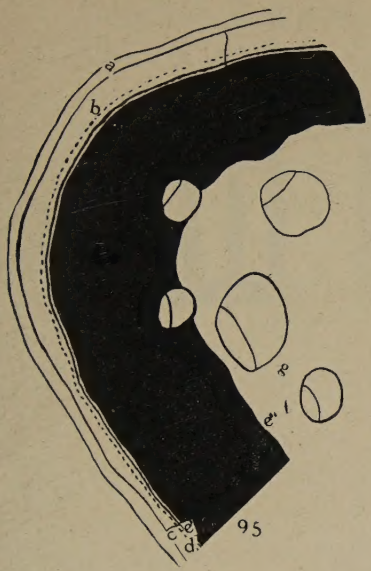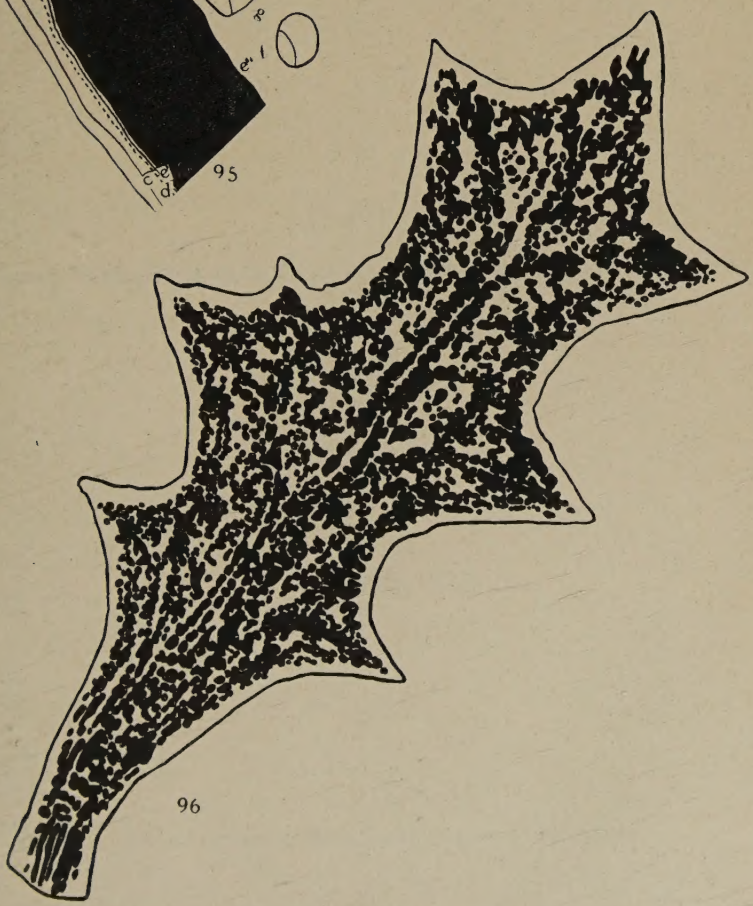
PLATE XIX.